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Corps of Engineers, United States Army, and Engineer Department at Large

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Published Quarterly at the Engineer School, Washington Barracks, D. C., by the School Board. NOTE: Authors alone are responsible for statements made and opinions expressed in their respective articles.

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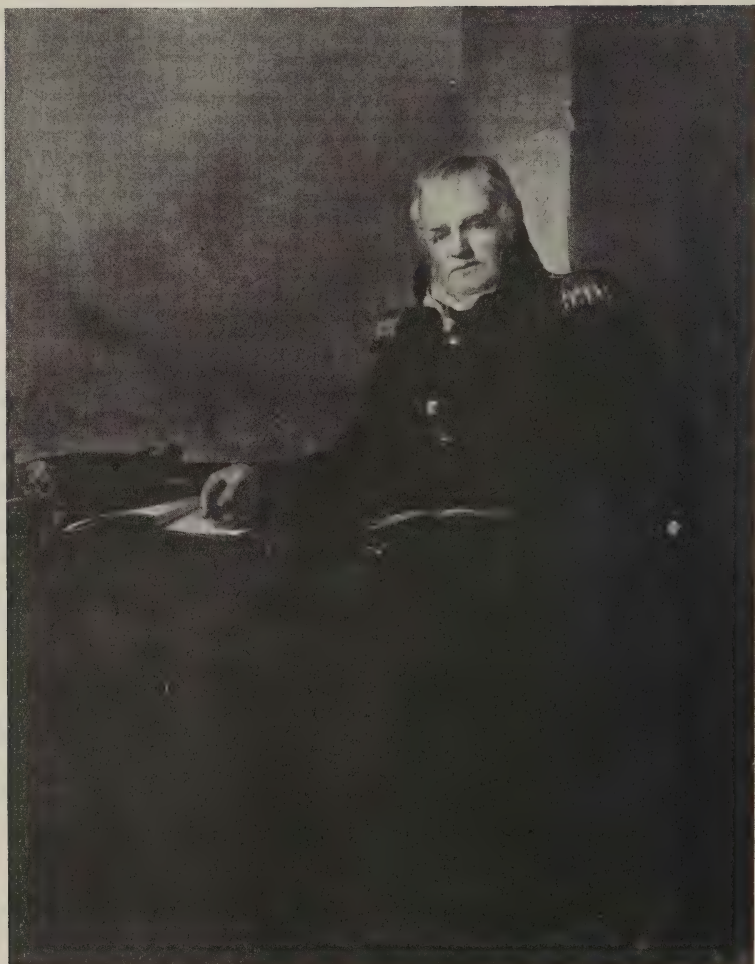
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Entry as Second Class matter, under the act of March 3, 1879, applied for at the post-office at Washington, D. C. Subscriptions, \$4.00 per year, in advance; single copies, \$1.00. Advertising rates on application. Address all communications to PROFESSIONAL MEMOIRS, Washington Barracks, D. C.



FROM THE PAINTING BY SULLY

SEE PAGE 41

COL. JONATHAN WILLIAMS
CHIEF ENGINEER, UNITED STATES ARMY
1802-1812
BORN 1750—DIED 1816

SABINE BANK LIGHT STATION, TEX.*

BY

T. P. BROWN
*Superintendent, Light-House
Establishment*

The site of this light-house is about 15 miles off-shore in the Gulf of Mexico, in about 16 feet of water at low tide, or 18 feet at high tide.

As officially described in the List of Lights and Fog Signals, it is "In 18 feet of water, on Sabine Bank, Gulf of Mexico, La., about 16 miles SSE. $\frac{5}{8}$ E. from Sabine Pass light-house," in latitude $29^{\circ} 28'$ ($15''$); longitude $93^{\circ} 44'$ ($7''$).

An examination of the chart will show that it is in one of the most exposed situations of the Gulf of Mexico. The southerly winds, which are the prevailing ones during the summer season, blowing over a long stretch of sea, cause an almost continual swell on the shoal that increased the difficulty of the work materially.

The winds from a southeasterly direction, which are the most frequent during the spring and summer, blow up through the Straits of Yucatan, the distance from the coast of South America in this direction being about 1,500 miles.

The nearest point at which the railroad can be reached is Sabine, Tex. From this point a branch road runs to Beaumont, Tex., connecting there with the main line of the Southern Pacific Railroad.

The first appropriation of \$40,000, authorizing the commencement of the work, was dated June 6, 1900. At intervals afterwards \$62,000 additional was appropriated, making the total of \$102,000.

A delay of nearly a year in completion was caused by having to wait for the last amount of \$12,000 needed for completion.

Borings made at the site to a depth beyond that to which the foundation would extend showed clear sand with a very slight admixture of foreign matter.

It was decided to ask bids on two kinds of structure, one a cylindrical iron tower on a caisson foundation, and the other

*The work of construction was done under the direction of Maj. W. E. Craighill, Corps of Engineers, by Messrs. Brown and Thompson, Superintendents.

a skeleton steel structure on screw piles. Bids were asked separately for the manufacture of the metal work and for the erection of the tower. The lowest bids for the cylindrical structure on a caisson foundation were as follows:

Metal work delivered at Sabine, Tex.	\$33,980.00
Erection, including furnishing all other materials except the lens apparatus	37,115.00
Total	<u>\$71,095.00</u>

For the skeleton tower:

Metal work as before	\$50,845.44
Erection, etc.	26,160.00
Total	<u>\$77,005.44</u>

It was decided to adopt the cylindrical tower on the caisson foundation.

The contract for furnishing the metal work was approved by the Secretary of the Treasury on March 10, 1903.

When, however, an effort was made to enter into contract with W. R. Taylor, of Norfolk, Va., the lowest bidder for the erection, he failed to make any response, and this part of the work was re-advertised.

This second advertisement was dated May 20, 1903, for proposals to be opened on June 26, 1903. As no bids were then received it became necessary to do the work by hired labor. Authority for this was given by the Light-House Board on July 11, 1903.

The structure is a circular cast iron tower filled with concrete up to 15.5 feet above the water level, except for the space left for cisterns. In the superstructure, which is lined with brick, there are the living rooms for the keepers, surmounted by the watch room and the lantern. The total height from the cutting edge to the top of the lantern is 121 feet. The focal plane is 72 feet above mean high water. In the cellar there are two air compressors operated by direct connected oil engines, supplying air for the fog signal, which consists of a Crosby automatic signal and a Daboll trumpet.

The lens apparatus is of the third order, five-panel, 360° illumination.

The caisson was built up of cast iron plates, and had the usual working chamber with circular steel shaft in the center for the air lock.

Copies of the record of the wind movement for ten years at Galveston, Tex., the nearest station of the Weather Bureau, were fur-

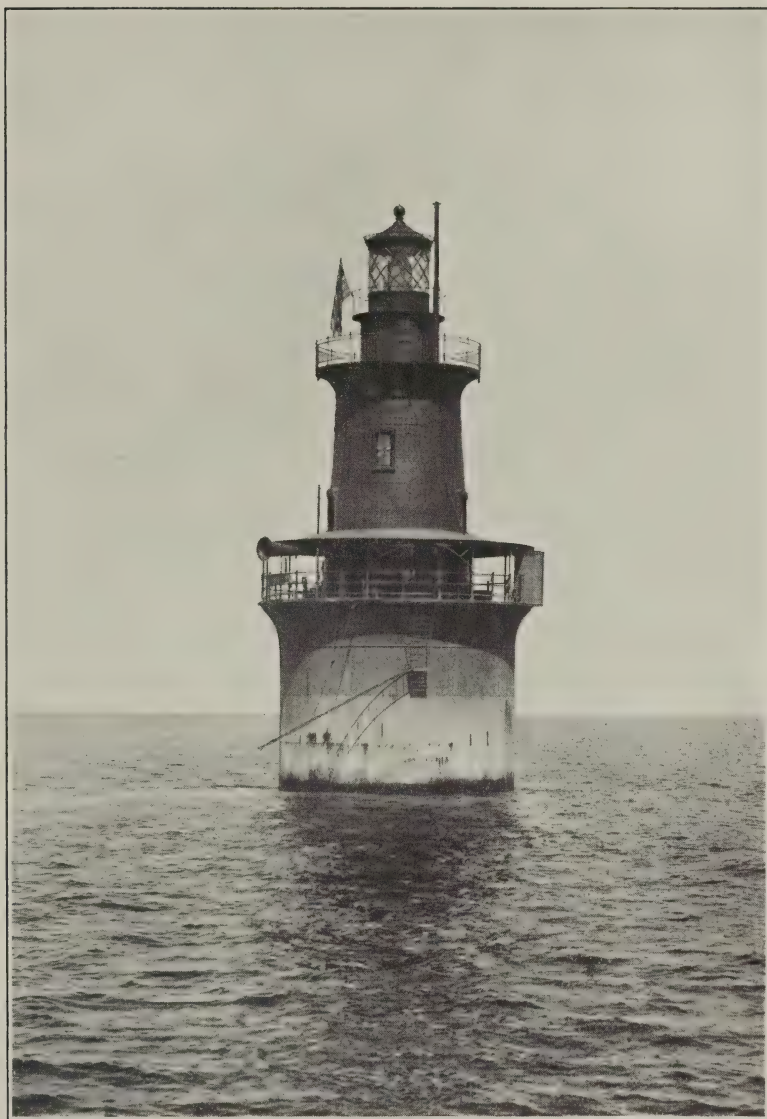


Fig. 1. Sabine Bank Light.

nished by that Bureau through the Light-House Board, and proved of invaluable assistance in determining the best season of the year for sinking the caisson.

The autumn months were not to be thought of because of the liability to hurricanes after about the 1st of September, and the winter months and March were also known to be too liable to gales.

A curve was plotted showing the mean daily wind movement for ten years, over the period from April 1 to August 31. The direction and force of the maximum wind for each day during the same period were also indicated.

An examination of the curve of wind movements indicated the time from June 10 to the 21st of July as being the most favorable period, except that about the 27th of June a considerable wind velocity might be expected.

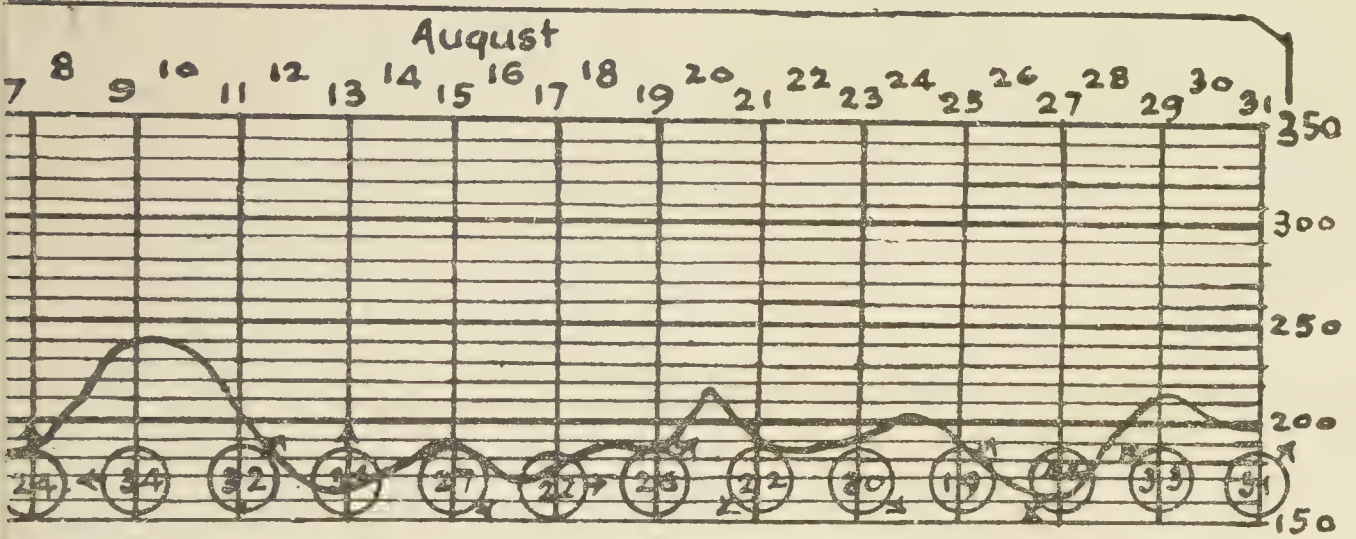
It was accordingly determined to use this time, and to arrange the plant so as to be able to finish sinking the caisson within one month's time, so as to allow some margin for delays in completion before the hurricane season.

Two general plans of operation were considered: first, to keep all of the material and plant afloat, except such of the machinery as could be placed on the caisson structure; second, to build a temporary platform to moor the caisson to, and to receive the plant and material. The second plan was adopted, and this fact I regard as contributing, more than any other one thing, to our success with the foundation.

The platform was a wooden pile structure (see Fig. 3), shaped so as to partially encircle the caisson when it was hauled into place. It was commenced on April 18, and completed on June 10, 1904.

The caisson was built at Sabine, about 16 miles from the site on Sabine Bank. It was commenced on February 10, and completed to top of third course of plates and launched on April 19, 1904. Two more courses of plates were then put on and 130 cubic yards of concrete laid over the working chamber, so as to cause the caisson to draw 16 feet, the maximum depth of water the channel would safely allow. It was ready for towing to the site on June 14, 1904.

The place of the air lock was on top of the air shaft, where it was finally secured after the caisson had been sunk to the bottom at the site. A water-tight false bottom of wood was built under the caisson, with edges projecting all around, to give it more flotation at the time of launching. After the caisson was afloat the false bottom was loaded with sand and then knocked off by tapping its



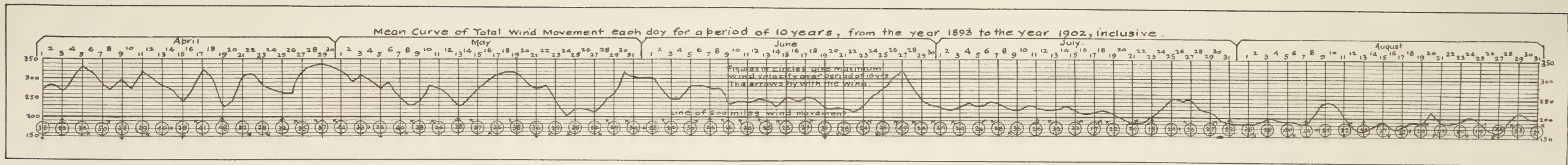


Fig. 2. Curve of wind movements.

SABINE BANK LIGHT STATION TEXAS.

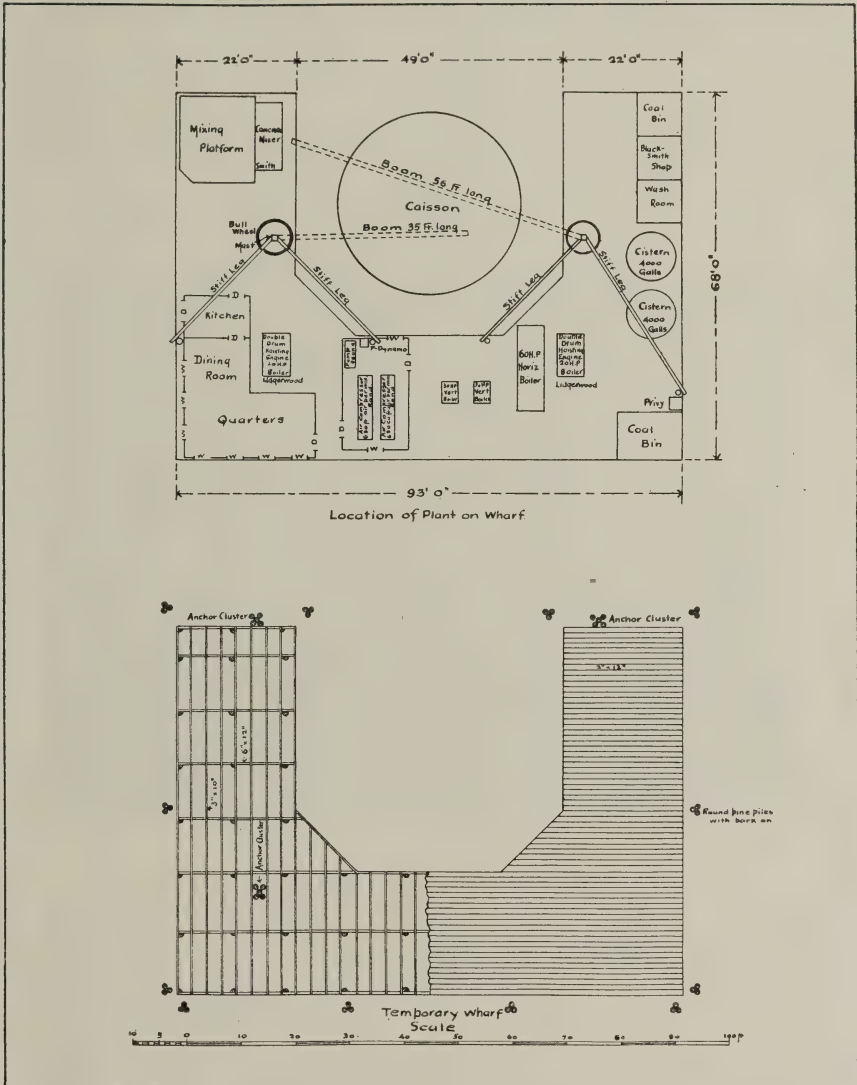


Fig. 3. Temporary working platform.

edge with a stick of timber in the pile driver. Inside the caisson a wooden cofferdam was constructed, arranged so as to leave a space between it and the walls of the caisson. The object of this was to permit water to be admitted into the inside of the cofferdam to sink the caisson, and yet leave the outer ring dry for placing concrete to weight the caisson down permanently on the bottom.

Radial partitions were also built in the cofferdam so as to prevent too much oscillation of the water before the caisson was on the bottom.

About 7.45 p. m., June 11, the caisson broke its moorings in a

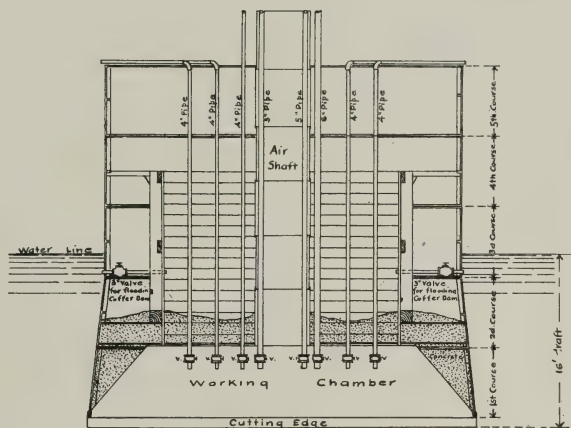


Fig. 4. Caisson.

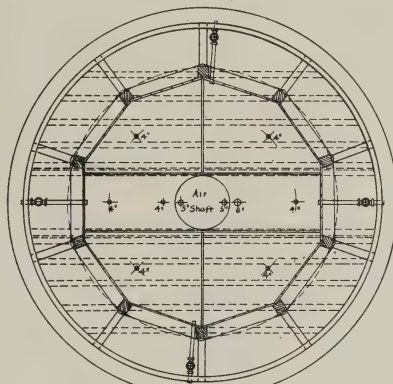
gale, and drifted down the channel as far as the Quarantine Station, where it was grounded and made fast with lines to the piles of the station. The chartered tug *Dorothy* and the light-house tender *Arbutus* almost immediately went to its rescue, and together towed it back to its moorings at the Southern Pacific wharf, arriving there about a half hour after midnight.

On June 20, everything was ready for towing the caisson to its place, but on account of the weather it was necessary to wait until June 22; and at 9.20 p. m. of that day the start was made. The evening was selected as the time for the start, so as to bring us to

SABINE BANK LIGHT STATION, TEXAS.



Sectional elevation of Caisson prepared for towing to site



Plan, Top of 3d Course

Scale 40' 30' 20' 10' 0'

Fig. 5. Details of caisson.

the site in the morning and allow all of daylight to make the caisson secure.

The tender *Arbutus* made fast with two hawsers to the caisson with the tug *Della* in front of her. The speed was necessarily so slow that the *Arbutus* would not steer, rendering the aid of the tug necessary. The caisson touched bottom once in the channel, due to the inattention of the tug captain. The tow arrived at the site at 8 o'clock in the morning of the 23d. During the night a breeze sprung up, making some sea, which caused the caisson to roll and pitch considerably. This sea was still running when we arrived at the site, but I decided, in spite of it, to put the caisson in place and sink it to the bottom with the water ballast. Straps had been put around the caisson, and four tackles arranged under the wharf so that it could be hauled into place and secured to four independent anchor clusters, so as not to touch the wharf or roll against it. The tackles used were each made up of 4-inch rope and two double 16-inch blocks. This was accomplished at 11.15 a. m. without accident, in spite of the sea. The valves were immediately opened so as to let the water enter and fill the interior of the cofferdam. In an hour and a half the caisson had sunk to the bottom, and on account of its motion in the sea had worked itself down into the sand until the roof of the working chamber was resting on the bottom. There it stopped almost perfectly level. During this interval, at times, its motions were very violent.

The 3-inch flooding valves proved to be too small, and they were supplemented by the 4-inch pump provided to supply water to the plant.

As soon as possible about 200 tons of rock, which had been made ready in advance on a lighter, were placed around the caisson.

The bottom was carefully watched during the early part of the work, and subsequently at intervals, but no changes in depths have been detected.

After the air-lock was bolted in place and the pressure turned on the working chamber, the process of sinking went forward without serious delay until 10 a. m. on July 24, almost exactly a month after the caisson arrived on the site; the air was turned off and the caisson men started for New York, where they had been hired. They were under the charge of Mr. F. C. Arthur, Superintendent in the Light-House Establishment, who had had much experience in this class of work in Chesapeake Bay. He had sixteen men, and the

Fig. 6. Launching ways for caisson.

total cost of their services, including superintendence and transportation to and from New York, was \$4,199.18.

The sand was blown out through two 4-inch pipes. The concrete for filling the working chamber was passed through a special air-lock provided for the purpose. Its capacity was 1 cubic yard. The men suffered a good deal from the heat, the heat of the Texas sun in July adding materially to that due to the compression of the air. The conditions were improved somewhat by boxing in the air pipes between the compressors and the air-lock, and keeping a circulation of water around them.

The prescribed depth was reached when the cutting edge was 39 feet below the surface of the water.

The work of filling the space above the working chamber was carried on without serious interruptions, except on account of the weather. Some difficulty was experienced in keeping a supply of material for concrete, and coal and water on the wharf.

The cost of the water alone, without including transporting it to the light-house from Sabine or Galveston, was \$807.28.

On August 23 work had to be suspended for lack of funds. An additional \$12,000 was estimated to be needed to complete the structure. A considerable part of the extra expense was due to the delay of a year which must be expected before a new appropriation would be available. In this time the platform would almost certainly be carried away on account of the piles being weakened by the teredo. The rest of the extra expense was on account of a decision of the Comptroller, forbidding the transfer of the plant to the account of Repairs to Light-Houses. It had been all purchased new and made rather more elaborate than might otherwise have been done, with this end in view.

During the following winter the \$12,000 asked for was granted by Congress, but it was not made immediately available, so that it could not be used until July 1, 1905. In the meantime the platform disappeared in a gale, carrying with it one derrick.

During the period of suspension it was necessary to show a light on the structure. At first an ordinary lens lantern was used, a watchman being employed to stay on the incomplected tower. This proved unsatisfactory, as the man nearly lost his life by his boat capsizing in attempting to go ashore after supplies. Finally, an acetylene gas machine, designed to burn ninety days, was borrowed from the Seventh District and installed on the tower. This was attended by the keeper of Sabine Pass light station. He made occa-

SABINE BANK LIGHT STATION, TEXAS.

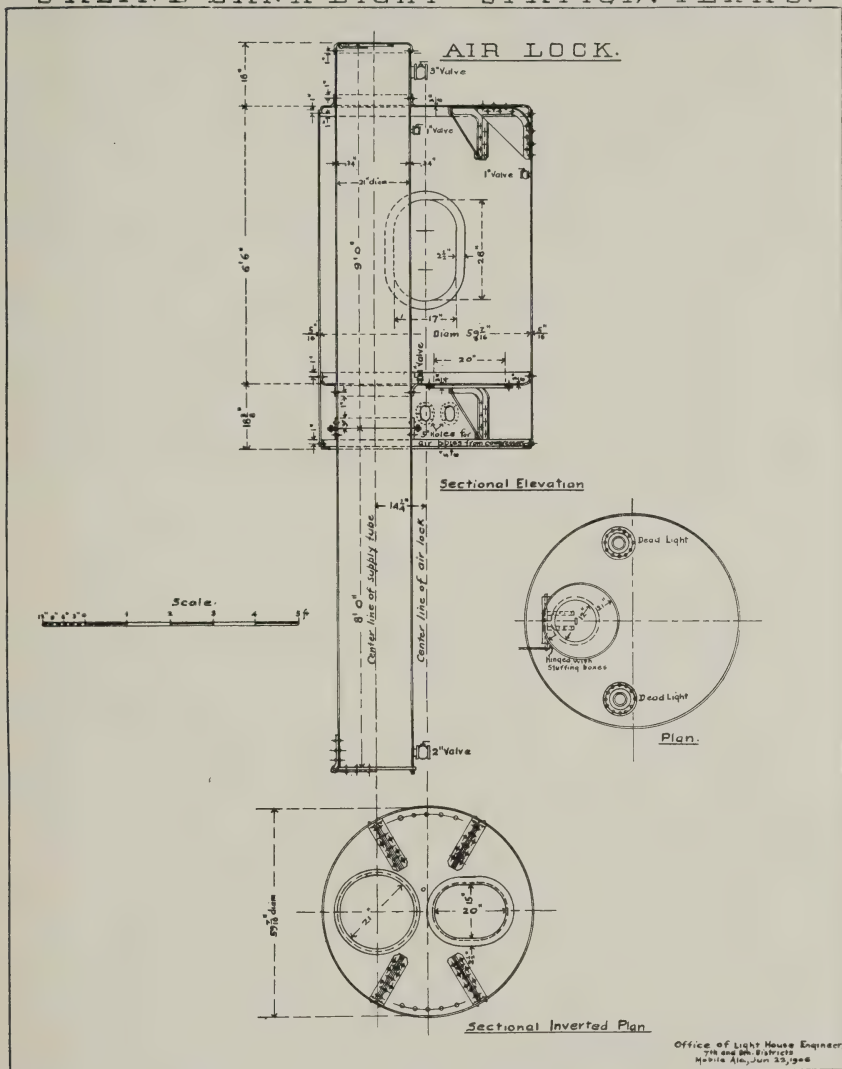


Fig. 7. Details of air lock.

sional visits, hiring a tug for the purpose. This arrangement satisfactorily solved the problem.

On the 15th of July, 1905, work was resumed and was carried on continuously until completion, about the 1st of March, 1906.

About 240 tons of additional rock were placed about the tower, making 480 tons in all.

The structure has shown no signs of settlement since the air pressure was taken off the working chamber. As near as can be determined it is perfectly plumb. A good proof of this was the fact that the ground surface of the iron table bearing the lens when fitted to its place was found to be so perfectly level as to require no adjustment to receive the lens.

The light was first shown on the 15th of March.

The plans did not provide for a wire screen around the lantern; on the first night two large mallard ducks flew against the glass of the lantern and broke two panes; some of the flying fragments damaged the lens slightly. An idea of the velocity of flight of the ducks can be formed when it is known that the glass broken was the best quality of plate glass one-fourth inch thick.

STATISTICAL INFORMATION.

1. Dates and amounts of appropriations:

June 6, 1900	\$40,000.00
March 3, 1901	40,000.00
April 28, 1904	10,000.00
March 3, 1905	12,000.00
Total	\$102,000.00

2. Date of both advertisements and abstract of bids:

First advertisement, November 24, 1902, asking bids for metal work and erection of "caisson" and "screw-pile" structures.

Following is the abstract of bids under above advertisement, opened January 8, 1903, by Lieut. Col. A. N. Damrell:

No.	Name and address of bidders.	Caisson structure.	
		Metal work.	Erection.
1	Russel Wheel & Foundry Co., Detroit, Mich.*	\$33,980.00	-----
2	Jno. P. McGuire, Cleveland, Ohio	42,000.00	-----
3	Atlanta Machine Works, Atlanta, Ga.	36,526.00	-----
4	W. R. Taylor, Norfolk, Va.†	-----	\$37,115.00
5	Allentown Rolling Mills, Allentown, Pa.	38,900.00	-----
6	Richmond Iron Works, Richmond, Va.	37,800.00	-----

* Lowest bid for metal work for caisson form structure.

† Sole bid for erection of caisson form of structure.

No.	Name and address of bidders.	Screw-pile structure.	
		Metal work.	Erection.
1	Jno. P. McGuire, Cleveland, Ohio -----	\$51,900.00	-----
2	Atlanta Machine Works, Atlanta, Ga. * -----	50,845.44	-----
3	W. R. Taylor, Norfolk, Va. † -----	-----	\$26,160.00
4	Allentown Rolling Mills, Allentown, Pa. -----	56,975.00	-----

* Lowest bid for metal work screw-pile structure.

† Sole bid for erection screw-pile structure.

Second advertisement, May 20, 1903, asking bids for erection of caisson structure. Bids were to have been opened June 26, 1903, by Maj. W. E. Craighill, but no bids were received.

3. Date of approval of contract for metal work:

Contract for metal work approved March 10, 1903. Metal work delivered in October, November, and December, 1903.

Contract for erection authorized by Board on February 2, 1903. W. R. Taylor failed to enter into contract.

4. Date of Board's authorization of day labor erection:

Board authorized erection of caisson structure on July 11, 1903, by day labor.

5. Weight of iron work, caisson, tower, and lantern complete, not including concrete: 695,394 pounds, approximately.

6. Plant purchased and cost of same:

Blocks -----	\$162.00
Trucks -----	20.00
Kitson lights. -----	448.12
Concrete mixer -----	856.64
Hoisting engines (2) -----	2,231.53
Derrick irons -----	589.00
Hydraulic jacks (2) -----	210.00
Generating set -----	426.00
Tools -----	316.46
Concrete tubs (4) -----	156.00
Boiler, 1 horizontal -----	413.00
Boilers, 2 vertical -----	352.00
Pump, 1 Deane -----	231.52
Pump, 1 centrifugal -----	470.00
Air compressors (2) -----	2,310.00
Miscellaneous -----	1,265.63
Total -----	\$10,457.90

7. For statistics from Weather Bureau, see Fig. 2.

8. Date of commencement and completion of platform:

Drove first pile for platform at site on April 18, 1904; platform completed on June 10, 1904.

9. Date of commencement and completion of caisson, amount of concrete in caisson, and draft of same when towed out:

Work of erection of caisson on launching ways commenced on February 10, 1904; caisson completed to top of third course and launched April 19, 1904; completed to top of fifth course and cofferdam completed, ready for towing out, on June 14, 1904. Caisson contained 130 cubic yards of concrete and had a draft of 16 feet when towed out.

10. Date of towing out caisson:

Caisson left Southern Pacific wharf in tow of tender *Arbutus* and tug *Della* at 9.20 p. m., June 22, 1904, arriving at site on Sabine Bank at 8 a. m., June 23, 1904. It was in proper position for sinking at 11.15 a. m., and securely sunk until roof of working chamber rested on bottom by 12.45 p. m.

11. Date of final cutting off of air; number of caisson men employed and cost of caisson work:

Air was finally cut off at 10 a. m., July 24, 1904.

The number of caisson men employed was seventeen, including Mr. F. C. Arthur, Superintendent, and the total cost for their services in sinking caisson to final depth, including salary and transportation to and from New York, was \$4,199.18.

12. Dates of suspension and resumption of work:

Work was suspended on August 23, 1904, and resumed on July 15, 1905.

13. Total concrete in caisson: 1,534 cubic yards, approximately.

14. Total red bricks and cost: 11,500 red pressed bricks; cost, \$327.50.

15. Total enameled bricks and cost: 12,683 enameled bricks; cost, \$1,453.08.

16. Date of completion:

Station completed and third order light first shown on March 15, 1906.

17. Cost in detail:

Photolithographing, printing, and advertising -----	\$694.04
Metal work as per contract -----	33,306.71
Plant -----	10,457.90
Rent of grounds and buildings -----	920.00
Bricks -----	2,140.68
Cement -----	4,845.00
Sand and rock -----	1,550.00
Air lock -----	1,000.00
Lumber and piles -----	2,447.52
Hire of barges and tugs -----	6,595.66
Coal and water -----	2,837.83
Hardware, fittings, etc. -----	2,018.06
Miscellaneous material used in connection with work -----	6,357.78
Crosby signal and Daboll trumpet -----	463.00
Third order lens and supplies -----	2,681.92
Labor and subsistence -----	21,960.87
Balance on hand to pay for rock and other liabilities incurred -----	1,723.03
Total -----	\$102,000.00

18. Number of vessels employed, dates, etc.:

Barge *Catherine*.—April 2-6, 1904, \$28.00.

Tug *Dorothy*.—April 26-30, 1904, \$250.00; May 1-31, 1904, \$1,500.00, and June 1-25, 1904, \$1,250.00.

Barge *Spindletop*.—April 18-19, 1904, \$16.00.

Barge *Eugenia*.—April 5-30, 1904, \$390.00; May 1-31, 1904, \$466.00; June 1-30, 1904, \$466.00, and July 1-15, 1904, \$253.00.

Tug *Della*.—June 21-23, 1904, \$90.00; December 7, 1904, \$40.00; March 20, 1905, \$40.00; May 8, 1905, \$40.00.

Barge *Calcasieu*.—June 13-August 20, 1904, \$1,133.33.

Barge *Trilby*.—August 20-September 26, 1905, \$633.33.

The total cost for hire of the vessels being \$6,595.66.

19. See page 16 for number of men employed each month.

20. Description of lens apparatus:

The lens apparatus is a fixed white of the third order, with an arc of illumination of 360°. There are five panels in the lens. eleven prisms in each panel above, and four prisms in each panel below the dioptric drum, or central belt of the lens; the central belt is 8¾ inches wide. The lens rests on a cast iron pedestal. An air pressure lamp, with three burners, is the illuminant.

21. Description of fog signal:

The fog signal is a Daboll trumpet, whose characteristic is five (5) seconds' blast, twenty-five seconds' silent interval, located on main gallery of tower, operated by compressed air from two air receivers supplied by two Hornsby-Akroyd oil engines (5 h. p.) located in cellar. The fog signal is supplied with Crosby automatic signal in duplicate.

A DEVICE FOR TESTING BALK

BY

CAPTAIN E. J. DENT
Corps of Engineers

The accompanying illustrations show a device recently used for testing the balk belonging to the reserve and advance guard ponton equipage at Vancouver Barracks.

The balk to be tested were of several varieties. A few of them were of white pine, these being probably the oldest. There were a large number of old balk of Douglas fir or similar material and some new fir balk. The reserve long balk were loaded to a maximum fiber stress of 3,974 pounds per square inch, the reserve trestle balk to a maximum stress of 4,060 pounds per square inch, the advance guard balk to a maximum fiber stress of 4,080 pounds per square inch. The object of the test was to make sure that each balk had about three-fourths of the strength with which it would ordinarily be credited. The equipage is ordinarily considered as having a factor of safety of about 4 and the test insures its having a factor of safety of about 3.

To apply the load a platform consisting of two 6 by 6 inch timbers about 20 feet long was constructed, the timbers being so spaced as to form a track for the limber of the forge wagon, and wheel guards and blocks were provided to keep the wheels on the track and to stop the limber at the proper points. The track platform was then supported at a point about 6 feet from one end and a counterweight of sand bags was placed so that when the front end of the track rested on the balk it was just balanced. No part of the applied load was due to the weight of the platform. A plank walk was built for the use of the man who handled the limber.

The applied load consisted of the forge wagon limber loaded with sand bags. By raising or lowering the tongue the load could be so balanced that it was borne entirely by the wheels, the man at the

end of the tongue carrying no weight. The balk were supported just inside of the cleats and a chock was placed to stop the limber exactly over the balk. The distance between supports and the load on the limber were varied to suit the kind of balk being tested. A stop was placed under the rear end of the track platform to limit its motion when the limber was run to the rear.

To test a balk the limber was run to the rear, as shown in Fig. 1; a balk was placed on the supports, the limber was run forward and



Fig. 1. Testing a balk. No load.

the load thus gradually applied until the wheels were stopped exactly over the balk by the end chocks. (See Fig. 2.) The tongue was raised or lowered till the load just balanced and the deflection was measured. The limber was then run to the rear, the balk was removed and a new balk was brought out and tested in the same manner. One man was able to handle the limber with sufficient ease.

The total number of white pine balk tested was 48, and as a result of the test 21 were rejected. Of the fir balk 122 were tested and 4 rejected. Three balk were actually broken, one being a new fir balk having a knot about three-fourths inch in diameter near its

middle point. Most of the balk rejected began cracking before the load was fully applied.

The deflection varied as follows:

Reserve long balk: Maximum, $12\frac{1}{4}$ inches; minimum, 5 inches.

Reserve trestle balk: Maximum, $5\frac{1}{4}$ inches; minimum, $4\frac{1}{2}$ inches.

Advance balk: Maximum, $9\frac{1}{2}$ inches; minimum, $4\frac{1}{2}$ inches.

The greatest deflection was noted in the case of the new fir balk.



Fig. 2. Testing a balk. Full Load.

It is possible that as these balk become older and more thoroughly seasoned they will become stiffer, although there is no reason to believe that at the time of the test they contained an excessive amount of moisture.

DECLINE OF WATER TRANSPORTATION ON WESTERN RIVERS

BY

COL. C. MCD. TOWNSEND
Corps of Engineers

INTRODUCTION

The arch enemy of the transportation of products, as of all motion, is what engineers term friction, and an essential element in the problem of cheap transportation consists in overcoming the necessary frictional resistance with the least—or, rather, the cheapest—expenditure of force. The friction caused by a solid body moving through a fluid is much less than that of any solid body moving over another solid; so that a waterway affords a means of reducing this frictional resistance to a minimum. To illustrate: If a team of horses pulls a plow through a field it encounters such a resistance that but little weight could be added to the plow without stalling the team. On a sled a greater load could be carried, and if a wagon be substituted the team will readily haul a ton of hay over the same ground and three or four tons over a paved city street. If the wheels of the wagon are flanged and placed on smooth steel rails, the team will readily haul over 10 tons. In a waterway the team will move a 200-ton canal boat.

Before the advent of the steam engine, when animal power was the sole means of propulsion on land, and the frictional resistance to be overcome was that of the country road, the waterway possessed such advantages as to become the only practical way of transporting commodities long distances, with the result that all products to be exported were hauled to the nearest waterway and shipped by river to a port at its mouth.

The invention of the steam engine has enormously reduced the cost of producing power, but has not, *per se*, materially affected the relative advantages of water over land transportation. The same amount of force developed from steam, or from horse flesh, is required to haul the wagon over a muddy road or the canal boat on a waterway; in fact, the waterway gains an advantage by the

exchange, as steam can be utilized more economically in the condensing engine of the steamship than in the non-condensing engine of the locomotive. The steam railway owes its development not so much to the steam as to the rail. The fact that the railway bed largely reduces the resistance to be overcome, when compared with the ordinary road, is the great advantage derived by the railway. But with the best roadbed, with gentle grade and slight curves, the railway is still at a disadvantage when compared with the waterway. The expenditure of coal that will propel a freight train carrying 1,000 tons of freight at a speed of 18 miles an hour on the Lake Shore & Michigan Southern Railway, will drive a steamboat with 5,000 tons at a rate of 12 miles an hour on the Great Lakes.

LATERAL FEEDERS AND TERMINAL FACILITIES

But there was introduced into the problem another element. Lines of water transportation are restricted in location. Rivers follow the thalwegs of large valleys and can only penetrate a small part of the country, while the location of railroads is not thus limited. They can be built so as to reach the field, the mine, the factory and the warehouse, but branch lines by rail or wagon are a necessity to an efficient water route, and in determining the cost of transportation by water the cost of these lateral feeders becomes a very important consideration and must when added to the cost of transportation on water be less than the cost of transportation by rail, or commerce will seek the rail route.

This self-evident fact can be expressed mathematically by the expression

$$ax + cz + d < by + d'$$

In which x , y , z represent the distance by river, rail and the connecting lines, a , b , c the rates per ton mile by these various methods of transportation and d , d' the cost of loading into boat and car. An analysis of this expression will throw light on the causes of the decline in river navigation.

Let us assume, for argument, that freight can be carried on rivers for short distances at the cheapest rate existing on the lakes, which is three-tenths of a mill per ton mile for coal as a return cargo from Erie ports to Duluth, a distance of nearly 1,000 miles, and is equivalent to assuming that freight can be carried on a river 100 miles for 3 cents a ton. Then let us imagine a town 10 miles from the river bank connected by rail to a river town 100

miles distant, but having only a country road extending to the river. A team of horses would have difficulty hauling a ton of freight to the river bank and returning in the same day. The ordinary American teamster would be inclined to charge for the job at least \$2.00. It therefore would cost to move the freight between the railroad terminals, via the water route, \$2.03, and the railroad could charge 2 cents per ton mile, or 66 2-3 times the assumed cost of water transportation, and the shipper would still save the entire cost of water transportation by shipping by rail.

If we assume that our imaginary town is connected to the river bank by an electric line which is willing to transport freight at twice the rate charged by the railroad, or 4 cents per ton mile, the water side of our mathematical expression would become 43 cents, and the railroad would have to reduce its charges from 2 cents to 4 mills per ton mile, or go out of business.

But the assumption that a short haul by water can be made at three-tenths of a mill per ton mile is an absurdity. A much more accurate assertion is that with the same expenditure of power about five times the amount of freight that can be moved by a railroad can be handled by water; but under such an assumption, according to our mathematical expression, the distance from river to our imaginary town that could profitably utilize a river route 100 miles long would be about 40 miles, if there was a connection by an electric road willing to carry freight at double the rail rates, while by an ordinary country road that limit would be reduced to less than 2 miles.

However, for a water route to be successful it is necessary to carry freight in large quantities. In such a case our connecting road would be carrying freight in carload lots. It could then transfer its car to a railroad without breaking bulk, and the d' of our mathematical expression would become 0; while it would have to unload its car into a boat. As it costs at least 25 cents to load a ton of freight into a boat or back into a car, and as a railroad with good grades can carry freight in train load lots at 2 mills per ton mile after the train has once been assembled, it is readily seen from our mathematical expression that a canal 250 miles in length will be unable to compete with railroads if it receives its freight from cars at one terminal and delivers to cars at the other.

This mathematical expression shows that the cost of the movement of freight over the lateral feeders practically confines the benefit to be derived from many waterways to the towns located on

their banks. As illustrative of this general proposition, the accompanying map has been prepared showing the maximum distances first-class freight is carried by rail from St. Louis in various directions for the amount per hundred pounds shown by the various lines resembling contours. Particular attention is invited to the 90-cent line through New Orleans as showing the great influence of the Mississippi River on freight rates to towns on its immediate banks, and the short distances inland these rates apply. If rates on lower grades of freight were analyzed still greater discrepancies would be observed.

UNECONOMIC EMPLOYMENT OF POWER IN STEAMBOATS

The halcyon days of steamboating were not days of cheap transportation. When the steamboat could pay for the cost of construction in a round trip it was decidedly the consumer that paid the freight. The great reduction in freight rates that has occurred in this country is due to the railroad rather than the steamboat. When railroads were first constructed, the cost of transportation was much greater than it is at present and the steamboat had at first an appreciable advantage, but the former have been shrewdly managed and the management has constantly sought to reduce the cost of transportation by improving their road beds, eliminating curves and reducing grades; and by increasing the size of cars and the weight of locomotives they have reduced by one-half the cost of train crew per ton mile, and have developed their terminal facilities to the greatest extent possible.

Where our waterways have been successful, as on the Great Lakes, a similar condition of affairs exists. With the deepening and straightening of the channels, steamboat owners have built larger vessels, so that their capacity has increased from 1,000 to 12,000 tons, with but slight increase in size of crew; and their terminal facilities have been improved to an extent unequalled in any other ports of the world, with the result that while a railroad can possibly carry coal at a rate of 2 mills per ton mile the lake rate from Erie ports to Duluth is about .3 of a mill per ton mile.

On the Mississippi River, on the other hand, the dimensions of boats have, if any change has been made, rather diminished in size. They are actuated by engines and boilers of similar design to those used on the river forty years ago, they ordinarily carry an enormous crew in proportion to their freight, and the terminal facilities consist of a gang plank over which freight is handled by hand. To

load a ton of freight into such boats costs more than it does to transport coal 1,000 miles on the Great Lakes and load and unload it. Under such methods commerce readily seeks the railroad, but on the Ohio River, where coal is loaded from tipples into barges, and moved down the river in large tows with a consequent minimum of crew to freight carried, the transportation by water holds its own and coal is transported at prices but slightly in excess of those on the Great Lakes.

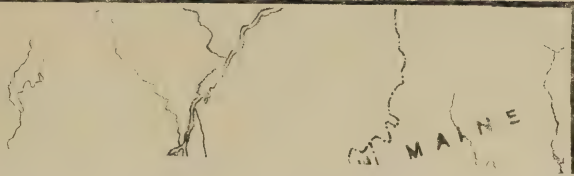
METHOD OF APPROPRIATIONS

But while the vessel owner on our rivers and canals has not kept pace with modern improvements, he is not entirely responsible for this defect. The improvement of the rivers themselves has been delayed so that he has not been justified in developing the steamboat economics that exist on the Great Lakes.

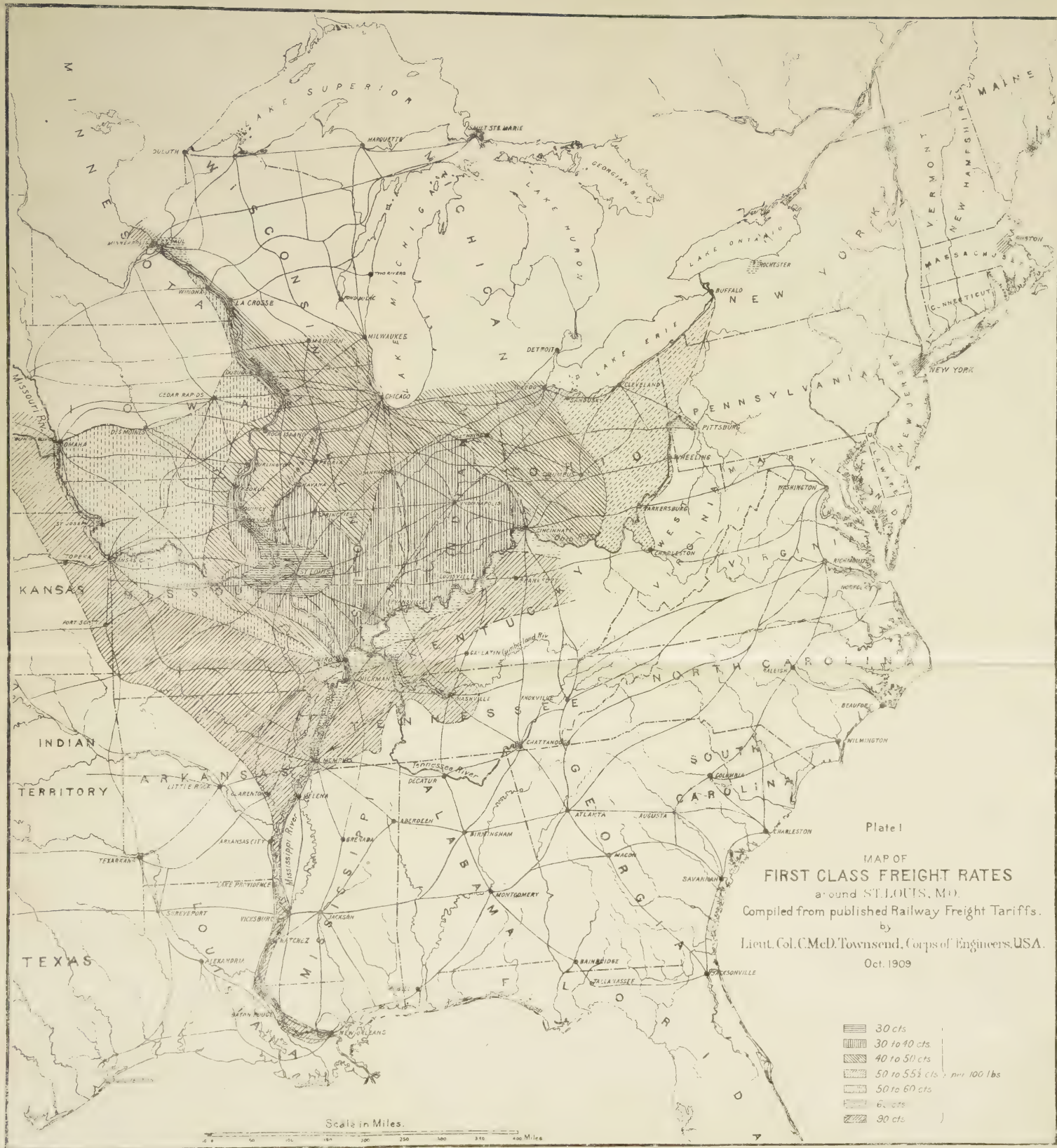
The United States in its development of waterways has, while expending large sums on the improvement of rivers, not been able to so concentrate its resources as to complete through routes. Thus the Government has appropriated large amounts for the Kanawha, Little Kanawha, Big Sandy, Muskingum, White, Green, and Barren, Kentucky, Cumberland and Tennessee rivers. Even if completed, the improvement of these rivers would be only of slight local value until the trunk line, the Ohio River, has been improved. On no river, except the Lower Mississippi, has a sufficient length of channel been improved to permit a transfer from car to boat and boat to car in competition with a railroad. The Monongahela River appears to be an exception, but on that river the success of the navigation is due to the fact that the mines are located on the river bank, and coal is towed to factories similarly located in the vicinity of Pittsburgh.

INSURANCE RATES AND INTEREST ON CAPITAL

There is a popular impression that if there were created a sufficient depth of water in our western rivers, so that they could be navigated by lake or ocean vessels, a great commerce would spring into existence, and the rapid increase of traffic on the Great Lakes is frequently quoted in proof of this. An analysis of conditions on the Great Lakes will indicate the error of such an assumption. A vessel on a trip from Duluth to Buffalo sails about 857 miles in the open lakes, 132 miles in connecting waters, and possibly 10 miles in harbors; 86 per cent of the journey being in the open lake and 14



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per cent in contracted waterways. In 1907 there were reported, exclusive of fires, 473 accidents on the lakes whose locality could be determined; of these about $28\frac{1}{2}$ per cent occurred in the open lakes, $43\frac{1}{2}$ per cent in connecting waters, and 28 per cent in harbors; 88 per cent of the collisions occurred in the contracted waterways, 37 per cent in the Detroit River alone. In 1908, when the commerce was not as great, 34 per cent of the accidents occurred in the lakes, and 66 per cent in contracted waterways. From the above it appears that over two-thirds the accidents occur in contracted waters, about one-seventh of the distance sailed. These accidents affect insurance rates and thus become a tax on commerce. The channels in the rivers connecting the Great Lakes are exceptionally wide and straight, so that insurance rates on ordinary rivers and canals should be much higher than on ocean or lake. I have been informed that insurance rates on the Canadian canals are as great as 10 per cent.

In a restricted waterway a vessel can not move as fast as in an open lake; this not only increases her coal bill, but also restricts her earning capacity. If she has to pass through locks there are still further delays. An American ocean freighter costs about \$70 per ton of freight carried; a lake freighter about \$40.00. Interest on the investment and insurance rates constitute large items in the cost of operation. Inspector Earl M. Nisen, of the Milwaukee office, has made a careful investigation of these elements of cost, and his conclusions are that if the cost of moving freight on the Great Lakes in vessels of 21-foot draft be assumed as 1.00, the cost of moving freight in lake vessels in a 21-foot canal without locks would be 1.46, in a 21-foot canal with locks 1.61, in a 14-foot vessel in the open lake 2.10, in a 14-foot canal without locks 3.07, in a 14-foot canal with locks 3.26. His conclusions were based on observation in the Sturgeon Bay Canal, and are considered very conservative.

The ordinary charges for transporting grain from Duluth to Buffalo, exclusive of loading and unloading, are .48 of a mill per ton mile. According to the conclusions of Mr. Nisen, a lake vessel in a 14-foot waterway from St. Louis to New Orleans would charge 1.47 mills per ton mile, and if an attempt was made to compete with a railroad running from Kansas City to the Gulf by diverting grain to St. Louis by rail thence to New Orleans by water, our mathematical expression shows the futility of the effort as long as freight rates from Kansas City to Galveston are $17\frac{1}{2}$ cents per

hundred and from Kansas City to St. Louis 12 cents. Interest on capital invested and cost of insurance are too high.

If, however, for the ocean or lake vessel can be substituted a barge which with its tow boat will cost only \$12 per ton of freight carried, the high rates of insurance and interest on capital invested are not as burdensome, and it is only by means of barge navigation that the commerce of our western waters can be successfully revived. The only successful competition with railroads that now exists is in coal carried in barges from Pittsburg to New Orleans and intermediate points and in timber rafted down the Upper Mississippi River.

UNEQUAL CHARGES BY RAILROADS TO RIVER AND INLAND TOWNS

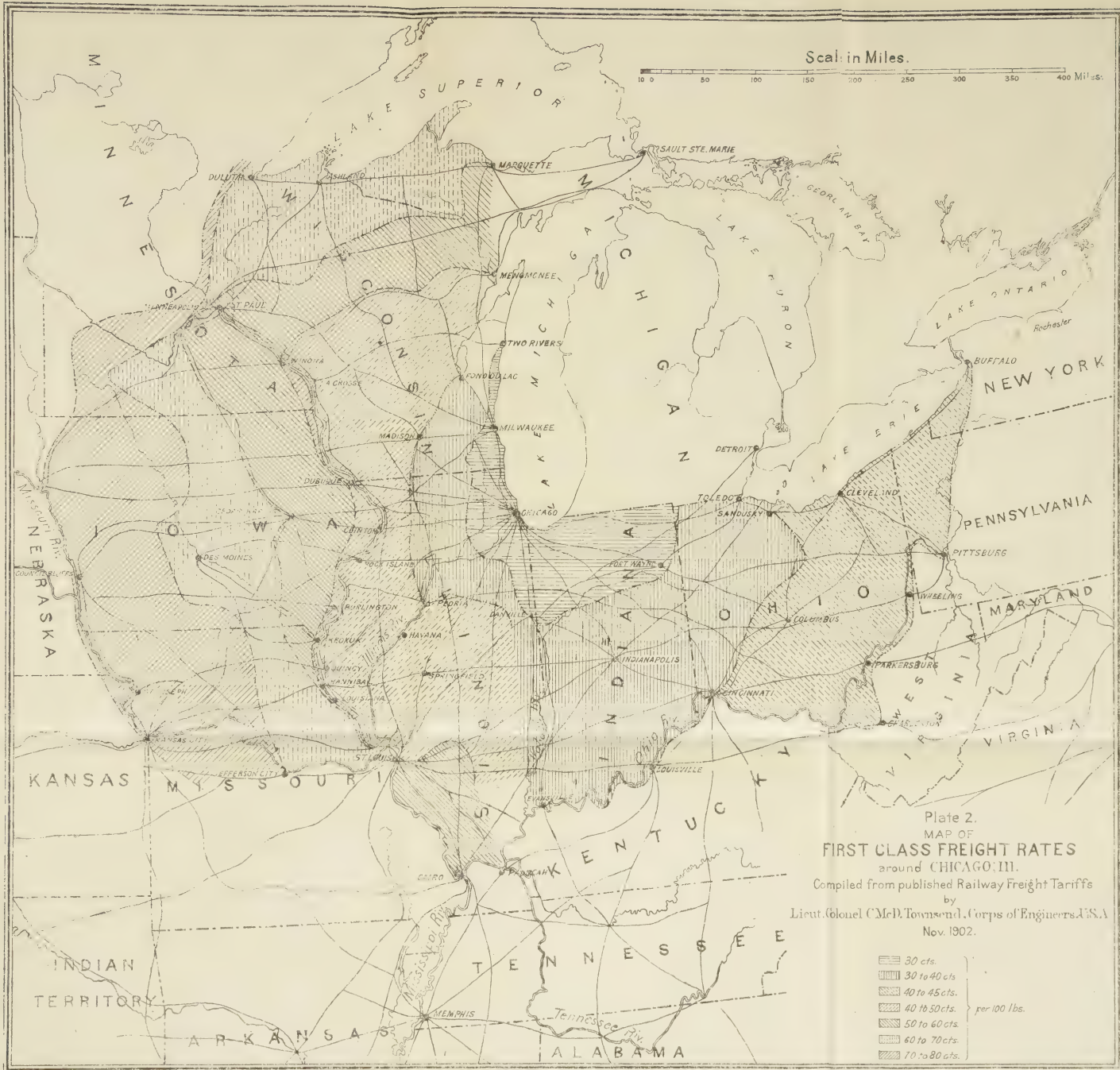
The interstate commerce law was designed to prevent undue discrimination by railroads, and to cause an equalization of freight rates, throughout the country; but under this law railroads have the right to give to towns having water competition specially low rates, and this affords the roads a powerful weapon against the steamboat. In addition to the interest on its bonds, many of the so-called operating expenses of a railroad are fixed charges independent of the quantity of freight carried. By assessing these fixed charges on the interior towns, the railroads can carry freight where there is water competition at very cheap rates, but at the expense of towns less favorably situated. On account of water competition, railroads out of Kansas City deliver freight at Shreveport, La., cheaper than to the Texas towns through which they pass, and the Nashville-Montgomery freight rates are less than those from Nashville to certain intermediate points. Towns on the banks of the Yazoo River and its tributaries have a lower rate on cotton to Memphis than their neighbors a few miles distant. There is also a certain incongruity in results. North of the Ohio River where Chicago competes with St. Louis for the trade of Mississippi River towns, the intermediate country obtains a benefit therefrom (see Plate 2), while interior towns are not thus favored by railroads radiating from St. Louis. (See Plate 1.) South of the Ohio River, rates to interior towns from both cities are excessive when compared with those to river towns. Rates on roads centering in Memphis are particularly eccentric. Class A freight from Memphis to Jackson, Miss., a distance of 211 miles, is charged 28 cents per hundred pounds, while from Memphis to New Orleans, 396 miles, the rate is 12 cents. For the same service the rate of 6

e in Miles.

200 250 300 350 400 Miles.



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mills per ton mile granted the river town is offset by a rate of 2.65 cents per ton mile to the locality less favorably situated. There is a unique arrangement of rates along the road from Memphis to Nashville, as partially shown on Plate 1.

SMALL COMPANIES INCAPABLE OF COMPETING WITH LARGE CORPORATIONS

The tendency of modern business is toward a concentration of capital in enormous corporations. This is particularly true of the business of transporting products. Each railroad in itself is a large corporation, but their concentration into railway systems which are practically under one management increases their efficiency. The interchange of freight between these systems has been perfected so that through bills of lading can be issued throughout the United States. The steamboat can usually only issue a bill of lading for a short distance, and even if there were great resultant economies by shipping by water over that distance, the inconveniences resulting from having to rebill the consignment of freight would tend to drive shippers to the larger corporation, and it is not to be expected that the railroads will voluntarily improve conditions in this respect.

The State of New York attempted to combat modern business methods by passing a law that no corporation designed to navigate any of the canals of the State shall have a capital stock exceeding \$50,000. The result was to accelerate the decline in transportation by canal.

On the Great Lakes, if you eliminate boats belonging to the railroads, the Steel Trust, the Coal Trust, and the Standard Oil Company, there is little commerce remaining. The small operator has practically disappeared. A Coal Trust also handles the great bulk of the freight on the Ohio River, and the Lumber Trust on the Upper Mississippi.

LOCATION OF WATERWAYS

But the great cause of the failure of waterways as a means of transportation in the United States is that they heretofore have not generally coincided with commercial routes. The river systems of the country flow generally in a southerly direction, while the trend of commerce has been east and west.

Until within the last ten years a railroad running north and south was generally a financial failure; river systems have followed

the same laws. Their commerce has been confined to the products on their immediate banks and that of not sufficient amount to justify their permanent improvement.*

The Mississippi River from St. Louis to New Orleans flows through a sparsely settled country. According to the census of 1900 there was between these points but one town on its banks of over 15,000 inhabitants (Memphis) and but six others with a population exceeding 5,000. The manufacturing industries or demands for manufactured articles in so thinly settled a region are slight. There are no mineral deposits along its banks, and its agricultural products are principally corn, cotton, sugar cane and rice. The alluvial soil of the Mississippi Valley with the heavy rainfall of this region renders its common roads almost impassable, so that a long haul to and from the river bank becomes very expensive and confines the commerce of the river to those products raised or expended on its immediate banks.†

"The waterways * * * do not flow in the direction of traffic, do not penetrate many regions in which traffic originates, nor flow to the points where materials are required, because they are circuitous and indirect, because they are often inaccessible and always unreliable, because they give slow service surrounded by danger and inconveniences, because they can not put forth branches into adjacent territory, but are confined to narrow, crooked, shifting channels with possibilities forever limited within narrow bounds by the laws of nature, and because economic interchange of traffic between rail lines and waterways is rendered impossible by laws that no man can modify or control."‡

CONCLUSION

It will thus be seen that the decline in shipping on our western rivers can be accounted for by natural laws, and it is not necessary to assume any underhand methods by the railroads to explain existing conditions. In fact, after a rather extensive correspondence, I can find no one willing to be quoted who makes such charges.

While the above is submitted as an explanation of the causes which have led to the decline of water transportation on our west-

* Report of Board of Engineers for Rivers and Harbors on Survey of Ohio River, House Document No. 492, 60th Congress, 1st session.

† Report of Board of Engineers upon Proposed 14-foot deep waterway from Chicago to New Orleans.—*Engineering News*, Vol. LXI, page 690.

‡ J. H. Peyton, *The American Transportation Problem*, page 193.

ern rivers, it is not considered a sufficient reason for abandoning their improvement.

A 9-foot waterway, ample for barge navigation, can be constructed from Chicago and Pittsburg to New Orleans, with 6-foot feeders in the Upper Mississippi, the Missouri and other tributaries, at the cost of a first-class double-track railroad, and can be maintained at far less expense. Such a waterway would connect the leading cities of the middle west by a line of transportation over which products could be carried much more cheaply than over a rail bed. Were such a line constructed, the first to appreciate its advantages would be the great transportation companies themselves. A waterway free to the people of the United States would also be free to the railroads, and whenever a railroad can save money by shipping freight down a river instead of over its own road bed, it will purchase a boat for that purpose, just as is now the case on the Great Lakes and Long Island Sound. The great corporations which are controlling our industries would force such action, and if the railroad failed to make rates to their satisfaction, they would be in a position to establish independent lines. With the waterways operated by the great transportation companies, the question of terminal facilities and branch lines would also soon be solved, as satisfactorily as it is on the Great Lakes.

Moreover, while for many years the trend of commerce was east and west, within the last few years there has been a large diversion of commerce to southern ports, which is reflected in the stock quotations of southern railroads; and with the completion of the Panama Canal this tendency may be expected to increase to some extent.

SINKING STONE DUMPS WITH WATER JET

BY

HENRY N. BABCOCK

Assistant Engineer

Ambrose Channel, the new entrance to New York Harbor, now being made 40 feet deep and 2,000 feet wide for a length of $7\frac{1}{2}$ miles, had a natural depth of 16 feet at its outer end, 24 to 30 feet in the inner part, with deeper holes at intervals. Excavation was begun in 1901, and in 1907 the channel was opened to navigation with 35 feet depth and 750 feet width; it is now opened for 40 feet depth and 1,000 feet width and is being widened by four large suction dredges built by the United States.

The natural bottom is sand, gravel and mud; the latter in places being so tenacious as to resemble clay. The stones found there were brought from excavations in and about New York City and dumped in the unimproved channel prior to the establishment in 1880 of a systematic Government supervision of dumping. They were in piles of very different sizes, the stones themselves ranging from small broken pieces to blocks of over 1 ton weight, and often mixed with brick, plaster, scrap tin and other rubbish. Two hundred and twenty-seven of these stone dumps have been already listed. Many of the smaller dumps, with stones somewhat scattered, have been undermined and sunk in the ordinary work of the dredges, probably including some which had not been located and listed.

The larger compact piles containing 50 to 500 yards of stones could not be gotten rid of in this way; the suction pipes would swerve off to the side, making considerable depths there, but not affecting the pile.

In the fall of 1907 it became important to open the channel immediately for new ships of too great draft to use the old 30-foot channel. Ambrose Channel then had an available depth of 35 feet at low tide except for certain of these stone dumps, and contracts were made for their removal. Twenty-two of these dumps nearest mid-channel were taken out at once and twenty-one more the fol-

lowing year. The work was done by dredges with clam-shell buckets, at a total cost for the forty-three stone dumps (17,029 cubic yards, about 55 per cent of which was stone and 45 per cent sand) of \$92,628.70, or an average of \$2,154.00 per stone pile, including inspection, sounding and sweeping. The work was expensive on account of the depth sought, the strong currents, the delay due to even light easterly wind, and an appreciable risk of sinking the plant unless withdrawn at the first sign of rough weather. It was made more expensive by insufficient competition; there being not more than three dredging concerns in New York capable of doing such work, and none of them really fitted for it. But it served the purpose of promptly providing safe navigation for large ships in a limited channel.

Afterwards, as the channel was enlarged, others of the stone dumps were in the way; but there was not the same emergency for their removal, and experiments were made to find a cheaper way to get rid of them. The Engineer District in which this work lies has a survey steamer, the *Manisecs*, about 100 feet long, fitted with derrick and hoisting engines; it had also a Worthington duplex pump, 7½ by 5 by 6 inches, with a 2½-inch discharge, which had been connected by hose to a 1½-inch reducer attached to 50 feet of double extra heavy pipe, for use in making wash borings. The boat was anchored over one of the smaller shoals (No. 30) which had considerable depths alongside, and a water-jet was driven into and along the edges of the stone pile during one tide (about five hours), throwing out the sand and sinking the stones from 28.2 feet depth to 36 feet. Subsequent experiments upon larger shoals were not so satisfactory; the only effective work of the jet seemed to be upon the edge of the shoal, and after that had been sunk the middle part would not follow, there being no ready escape for the sand.

When the regular channel excavations had progressed so that it was practicable to take off one of the dredges at intervals, work on the stone dumps was resumed by a method which has proved efficient and comparatively economical, as follows:

The location of the shoal is marked by range-buoys (the distance from shore being 3 to 4 miles) and one of the dredges is anchored so that her suction pipes lower at the edge of the stones. The dredge used for this purpose so far has been the *Navesink*, a steel sea-going suction dredge, 300 feet long, with bin capacity of 3,000 yards, and with two 20-inch suction pipes. This is done at the be-

ginning of a tide, so that she may work for several hours without changing her anchors. With good seamanship, anchoring and getting correctly located require on an average one hour and a quarter. Then the *Navesink* excavates pits as deep as her pipes will permit, 55 to 60 feet, removing the sand from all sides of the shoal and carrying it to sea. The *Manisees* then anchors over the stones and turns her jet into it, washing out the sand into the dredged pits alongside and undermining the stones. The larger stone piles can not be sunk at one operation; usually the *Navesink* works parts of three or four tides on the same shoal, and the *Manisees* often has to go back a second or third time. When no more shoal spots are found by sounding, a sweep is run over the place to make sure of the result.

The *Manisees* has recently been fitted with a larger pump, a Davidson single pump, 18 by 10½ by 18 inches, with separate connections for a 5-inch and a 2-inch hose. The 5-inch hose is used with a 4-inch pipe, 50 feet long, ending in a 1½-inch nozzle. The pipe is heavy and difficult to control in a strong tide-way, and when the nozzle touches bottom, the pressure rises often sufficiently to part the hose from the couplings, notwithstanding a relief valve at the top of the pipe. The 2½-inch hose maintains better pressure and is found more practicable to work with in such depths and currents as exist in Ambrose Channel.

Since March 24, 1909, several large stone piles have been wholly sunk to more than 40 feet depth, two others to 39 and 37 feet, respectively, and others to less depths, work not being completed. The table on page 34 gives details of the work and cost for the seven piles which have been completely sunk.

Average cost of removing each shoal, \$390.24.

In addition, Shoal No. 27 has been deepened to 39 feet and Shoal No. 52-a to 38 feet. Three other shoals have been partly removed and are now being worked upon.

The average cost of removing forty-three shoals under contract was \$2,160.00 each.

The sketch (Fig. 1) shows sections, up and down stream, on two of the stone dumps which have been sunk below 40 feet depth by the *Navesink* and *Manisees*.

The details of arrangement and the operation of water-jetting have been in charge of Mr. Glen E. Balch, Assistant Engineer, to whose skill and energy the success of the work has been largely due.

SECTIONS ON OLD STONE DUMPS.

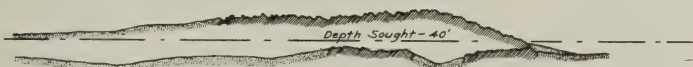
Showing Depths (Upper Line) before Work was Commenced,
and Depths (Lower Line) after Work was Completed.

SCALE = 30 Ft. to the Inch

Note—But few of the stones were raised by the Navesink and carried away: probably never to exceed 20%.

SHOAL NO. 56.

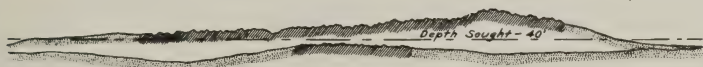
Mean Low Water Level



On this shoal dredge Navesink worked 14 h. 45 m., cost \$295.00 removing 4550 cu yds. of sand and small
and str. Manisees " 13 h 30 m., " 135.00 stones, excavating around edge of pile,
Total cost, \$430.00 sinking the rest of the stone by jet

SHOAL NO. 91.

Mean Low Water Level



On this shoal dredge Navesink worked 21 h 35 m., cost \$431.67 removing 8382 cu yds. of sand and small
and str. Manisees " 8 h 00 m., " 80.00 stones, mainly around edge of pile.
Total cost, \$511.67

Fig. 1.

Details and Cost of Work.

No. of Shoal.	Navesink.					Manitesees.						
	Original depth.	Cubic yards removed.	Time anchoring and shifting.	Time pumping.	Total time.	Cost at \$20.00 per hour.	Sounding.	Pumping.	Sweeping.	Total time.	Cost at \$10.00 per hour.	Total cost.
56	<i>Fath.</i> 29.0	4,550	<i>h. m.</i> 4 35	<i>h. m.</i> 10 10	<i>h. m.</i> 14 45	\$295.00	<i>h. m.</i> 1 00	<i>h. m.</i> 10 30	<i>h. m.</i> 2 00	<i>Hours.</i> 13½	\$135.00	\$430.00
91	29.8	8,382	5 30	16 5	21 35	431.67	0 30	6 00	1 30	8	80.00	511.67
92	27.5	6,099	3 50	11 5	14 55	298.33	1 00	6 00	5 00	12	120.00	418.33
50	29.7	8,304	6 25	16 5	22 30	450.00	3 00	7 30	1 30	12	120.00	570.00
52	29.2	2,816	0 25	3 25	3 50	76.67	1 30	9 00	1 30	12	120.00	196.67
52-b	27.0	5,022	2 45	7 50	10 35	211.67	1 30	6 00	2 00	9½	95.00	306.67
94	36.5	5,935	4 40	8 30	13 10	263.33	2 30	0	1 00	3½	35.00	298.30
Totals	-----	41,108	28 10	73 10	101 20	\$2,026.67	11 00	45 00	14 30	70½	\$705.00	\$2,731.67

THE OHIO RIVER*

BY

CAPT. F. W. ALTSTAETTER

Corps of Engineers

I am glad of this opportunity to speak in behalf of the river engineer, for I have observed a tendency to question the propriety of placing the army engineer in charge of work of this character. Therefore, I should like to trace in brief the natural and logical course that led to this assignment.

In 1802 Congress passed an act stating that the Corps of Engineers of the United States Army should consist of a certain number of officers and a certain number of cadets, the latter to be stationed at West Point, N. Y., and to constitute a military academy. President Jefferson was not a military enthusiast, and it is known that when he signed this act he contemplated an institution at West Point which would supply the country with engineers for civil as well as military purposes, but there was no provision made for the education of line officers of the Army. This was the first technical school established in the United States, nor was there any other until the Rensselaer Polytechnic Institute was founded twenty-three years later, followed by the Sheffield Scientific School in the forties.

Our technical schools, which are now the admiration of the world, have practically all come into existence in the second half of the nineteenth century. During the first half of that century our country was almost devoid of engineering knowledge except such as West Point provided. It was therefore natural when Congress in 1820 launched forth on the scheme of improving the Ohio River that they should turn to the Army for engineers.

For many years after this the army engineers were in great demand. Not only did our National Government use these men, but civil life took many of them by reason of the greater emolu-

* Address delivered at Wheeling, W. Va., November 3, 1909, at the celebration of the completion of Lock and Dam No. 13, Ohio River.

ments which it afforded, while even foreign Governments were known to call on them for services.

It was during the early part of the last century that many of our railroads were planned and built, and the number of West Point graduates who figured in their construction is an indication of their activity and prominence at the time. The Baltimore & Ohio was the earliest important railroad enterprise undertaken in the United States. Three officers of the Corps of Engineers were chosen as a board to select a proper route to the Ohio, where the earlier road terminated. These with other officers were actually engaged in building the line, and the first steam locomotive ever run in this country was run on rails laid by them.

Almost every important railroad on this continent built about that time was built partly or entirely by some West Point men. Among these I might mention the Lake Shore & Michigan Southern, the Erie, the Boston & Albany, the Mobile & Ohio, the Pittsburgh, Fort Wayne & Chicago, the Panama Railroad, the first railroad built in Cuba, the first railroad in Mexico.

In 1835 the Russian Government decided to build a railroad from Moscow to St. Petersburg, and appointed a commission to study the subject. The commission traveled all over the civilized world and extended their studies for seven years, at the end of which time they advised the Czar to send for Whistler, an American army engineer, and he would build it for him. The Czar did send for Whistler, who began the Imperial Railway system of Russia, on lines so broad and true that in some railroad features the rest of Europe has never been able to overcome the lead that Russia thus acquired.

But railroading is not the only thing these early graduates did; they built public buildings and light-houses; they explored unknown parts of the country; one of them established the Coast and Geodetic Survey, and for eighteen years served as its head; they were employed by New York and other cities in their most important municipal works; they founded schools and colleges; and did much for the advancement of science.

I speak of this work which they accomplished simply to show how natural it was that after Congress had once been led to put river and harbor work in their hands it should leave it with them during that period.

Since these early days the country has been filled with many able men in nearly all walks of engineering life, and West Point has

lost her unique engineering position. But there has never been a body of men other than the army engineers with their assistants who have devoted themselves to river and harbor improvements, and Congress has never seen fit to take away from them the duty which fell so naturally into their hands and which they have always attempted to discharge to the interests of the Government they were serving.

As for the work on the Ohio, Congress first started it by providing for a survey in 1820, after which money was appropriated for building dikes and for the removal of snags. These dikes consist essentially of long, low, narrow mounds of rock projecting from the bank and held in place by timber cribwork. At ordinary stages these dikes concentrate the flow of the water at the shallow points and scour them to greater depth.

Later Congress authorized dredges for assisting in the work of deepening the channels, but as the river increased in importance as an artery of communication these methods did not give the desired depth and movable dams were suggested by Major Merrill, for which Congress appropriated \$100,000 in 1875. This money, Congress said, was to be used for beginning the construction of a movable dam for the purposes of testing the best method of improving the navigability of the Ohio River and its tributaries. This dam was constructed at Davis Island and was opened in 1885. From the time it was completed to the present time it has been a perfect demonstration of what can be done for the river by such methods. Since its completion, five other dams have been built in the Pittsburgh District; one is just completed below Wheeling (which we are celebrating to-day), six others are under process of construction; and the Louisville and Portland Canal is also under improvement. In addition, surveys are practically completed and plans will be submitted to Congress at its next session covering all dams needed between Pittsburgh and No. 29 below the mouth of the Big Sandy River.

This account of work on the Ohio River seems a narrative of simple and placid progress of events, but as regards the engineering questions at least it has by no means been such. The men who proposed and carried out the work so far done have been opposed at every point by contrary ideas. They have been accused of lack of knowledge, of lack of interest, of opposition to progress, of failure to appreciate the needs of the river—and, I might add, I feel a little sensitive on this subject, as I have been cited myself in a

recent magazine as a horrible example of the petrified conservatism of the Corps of Engineers. From the beginning, the engineering features of the Ohio have been a source of discussion on the part of engineers and pseudo engineers, projects and counter projects have been advocated and ignorance seems never to have discouraged anyone from launching a new theory of improvement.

At one time a Mr. Haupt proposed the construction of longitudinal banks along one side of the river to create an artificial channel or canal 200 feet wide; but he received no support from Washington.

Next some dreamer suggested that a channel be cut from Lake Erie through to the Ohio so that when the river reached a low stage water could be turned in from Lake Erie and a 6-foot depth maintained. And when it was shown that this was not feasible a prompt reply was made that Lake Chautauqua should be used as a storage reservoir, and as it did not afford sufficient flow a pumping plant should be put in to draw the extra water from Lake Erie. As the cost of this little scheme was estimated at \$625,000,000 (approximately ten times the present project by locks and dams) Congress gave it a deaf ear.

As we contemplate these projects now, they seem absurd, and we wonder why people ever gave them credence; but they received important consideration in their day, and the Ohio River is not yet free from their kind.

At the present time we still find the old reservoir scheme strongly advocated. In 1866 Mr. C. Ellett advocated the building of reservoirs at the headquarters of the various tributaries, and releasing the impounded water when necessary so that the stage would never drop below 6 feet. At that time the idea was shown to be impracticable, but it has recently been resurrected for producing a 9-foot stage, and its advocates are still clamoring for its adoption. In its revised form this project has been made a more attractive pill for the country to swallow by saying that great water power could be developed at the various reservoir sites, that floods would be reduced, and that the tributaries would be improved at the same time; while on the tail of the project we find tied a proviso that forests would have to be planted in the watersheds above the reservoirs to keep debris from washing into them and filling them up. In this scheme large districts are flooded, people are driven from their homes, towns and smiling valleys are ruthlessly turned into reservoir sites; highways and railways are

covered with the penned-up waters, farms are turned into forests, and we are calmly told that all these things are to be done in the interests of navigation. Truly, navigation is asked to carry a heavy burden.

The advocates of this project speak of \$125,000,000 for its completion; but a little study indicates that a thousand millions is a more conservative estimate.

I had occasion to investigate some phases of this project, and find that it does not improve on acquaintance. It is found, for example, that reservoirs are proposed which if built would never be filled, because all the water from their drainage area would not fill them in a year, and we would have the spectacle of a big dam without the water behind it to make it useful. Again it is found that if every drop that drains from the Upper Ohio were stored in reservoirs and this water released with mathematical uniformity and precision, that section of the river, which is now often above a 9-foot stage, would then, due to lack of water, be below that stage 365 days in a year and 366 days in leap years.

It was remarked, I believe, at the last meeting of the West Virginia State Board of Trade that no reputable hydraulic engineer had ever favored the lock-and-dam system for the Ohio River. If this be true, no reputable hydraulic engineer has ever expressed any opinion on the subject, because every engineer who has made a study of the hydraulics and navigability of rivers and who has expressed any opinion has expressed it in favor of locks and dams as opposed to the reservoirs; and if there be any such engineer living, in the Government service or out, who has ever favored the reservoir system, then I have never heard of him, and I have kept in pretty close touch with the subject.

The reservoir scheme is favored by some very able men; but their ability lies in the lines of their life work, which is sometimes forestry, sometimes geological surveying, but never improvement of navigation. If I speak thus strongly against the reservoir project, I do it advisedly, because I understand its friends are girding their loins for a new assault on Congress at the next session; and should they force doubt into the minds of some members of the River and Harbor Committee, we might find the improvement delayed for years while investigations were being made, because Congress is not a body to launch into any large project until they are sure of what they are doing. It is a flattering commentary on the abiding sound judgment of our National Legislature that in all the

eighty-nine years it has been spending money on the Ohio, it has given scant encouragement to the proposers of fanciful projects, and let us hope this record will not be broken now.

There is another point of which I wish to speak. When God made the face of the earth, He decided then and there in what direction the main arteries of communication and transportation should lie. The mountains of the country, the length and depth of its streams, the location of its lakes, the configuration of its seaboard—these are the things which tell the lines trade must take. Man is enabled at the sacrifice of much time and energy to change these routes to some extent, but even then his power to do so is limited. As an illustration: When Frederick the Great, King of Prussia, made war on Maria Teresa, Queen of Austria, in 1756, he gathered his armies on the borders of Silicia and then moved them by four separate routes over the hills and through part of Bohemia to meet the Austrian forces. The mountains and the rivers told him where he must go and where he could not go. Practically no choice was left him between the starting point and the point to which he wished to bring his armies. In 1866, one hundred and ten years later, we find modern Prussia at war again with modern Austria. Von Moltke, the greatest strategist since Napoleon's time, was told long in advance that such a war was inevitable and that he must make his plans against Austria.

Since Frederick's time monarchies had been made and dynasties had fallen, railroads and steamboats and telegraph lines and telephone systems have come into existence. Everything connected with communication and transportation and movement of men and materials seems to have changed except nature herself. Von Moltke studied his program for moving his men, his munitions, and supplies, from Silicia into Austria, and after more than a year's work he was driven to the identical lines that Frederick the Great had used, they being nature's own paths. The result was a brilliant victory for his king.

So is it with the Ohio River. From early days people have moved down the river when they could. It was nature's avenue of communication between parts of the country bordering on its banks. The settlers used it to reach their new homes, and in the days of the National Pike we find the river and the pike the combined route between the east and the west.

In recent years railroads have been built along the banks of the river as a sort of substitute for it, but even though refusing to use

it we could not stray far from this natural path. And now after years of railway expansion, we find car shortages, lack of terminal facilities, and congestion of traffic staring us in the face, while the river calmly sweeps along, as ready as ever to carry our burdens would we but lay them on its bosom. It is the inevitable law—we have strayed from nature and now we are being driven back to her. But let us return, assured of our position, assured that we found the true route along the Ohio Valley, and with the courage of conviction, press forward the completion of this adequate system of locks and dams from the source of the Ohio River to its mouth.

Jonathan Williams

Jonathan Williams (see frontispiece) was born at Boston, Mass., May 20, 1750; and died at Philadelphia, Pa., May 16, 1816. He was secretary to his granduncle, Benjamin Franklin, while the latter was ambassador to France, and while abroad read widely concerning fortification and made an especial study of military science. He returned with Franklin in 1785 and was for some years a judge of common pleas at Philadelphia. In 1801 he entered the army, serving in the Second Regiment of Artillerists and Engineers and as Inspector of Fortifications, and taking command of West Point and the Military Academy in 1802-3. He resigned in the year last named, but returned to the army in 1805 as Chief Engineer and Superintendent at West Point. While in charge of the fortifications of New York he built Fort Columbus and Castle Williams on Governors Island, Castle Clinton (Castle Garden), and Fort Gansevoort. On the breaking out of the War of 1812, as senior officer at Castle Williams he claimed command of that fort, but because of complications arising from the protests of other officers against this assignment, he resigned.

He was elected to Congress in 1814, but did not take his seat. As the first person in the United States to apply the principles of scientific engineering he has often been called "the father of the Corps of Engineers."

He published *The Use of the Thermometer in Navigation* (1799) and translated *Elements of Fortification* (1801) and *Kosciusko's Manœuvres for Horse Artillery* (1808).—*From The Americana and Humphreys' Historical Sketch of the Corps of Engineers.*

A MACHINE FOR CUTTING OFF PILES

BY

CLARENCE COLEMAN

*United States Assistant
Engineer*

The heads of the rubble mound breakwaters at Superior Entry, Wis., will consist of large timber cribs filled with stone ballast and seated on a foundation of piles cut off at an elevation of 2 feet above the bottom of the lake and a maximum depth of 35 feet below low-water datum. These piles are jettied in place with a water jet working under a pressure of 600 pounds per square inch, and then settled to their final bearing with a 3,500-pound hammer. They are placed butt ends down and driven from 15 to 18 feet in the sand. It is necessary that these piles should be cut off at an even grade for the reception of the cribs.

Ordinarily the work of cutting off piles under water is performed by divers, by machines using either circular or straight cross-cut saws working from a trestle or by machines working from floating scows. In the case under consideration the conditions as to depth of water, risk from storms, and the interference with work on account of the existence of rapid currents, necessitated the design of an original machine for performing this work with accuracy and dispatch. With this in view a set of ordinary pile driver leads were erected on a small scow, as shown on the accompanying drawing. A mandrel beam 12 by 16 inches by 56 feet carries a steel shaft 3 7-16 inch diameter, 50 feet long. This shaft is mounted on the mandrel beam with proper standards as shown, and the beam with the shaft is installed between the leads in such a manner as to travel vertically by means of a small hoisting engine on the scow to any desired elevation. A 48-inch circular cross-cut saw is attached to the lower end of the steel shaft, which is rotated by a belt connected with the driving engine on the scow. The steam is furnished by a 30-horsepower horizontal boiler for the entire plant. The special feature of this machine is the guide bracket constructed of steel and equipped with two double flanged trolley

wheels designed to move on an 8 by 8 inch timber cap which is placed on the row or bent of piles just forward of the row which is intended to be cut off. These caps are moved ahead one row as often as the row immediately behind is cut, and lightly spiked in place until the next row has been cut, and so on until each row or bent has been cut. For cutting the last row three special piles are driven for carrying the cap and afterwards removed. As stated, the guide bracket is the special feature, in that it insures cutting the piles to a perfectly even grade at the depth desired. It will be

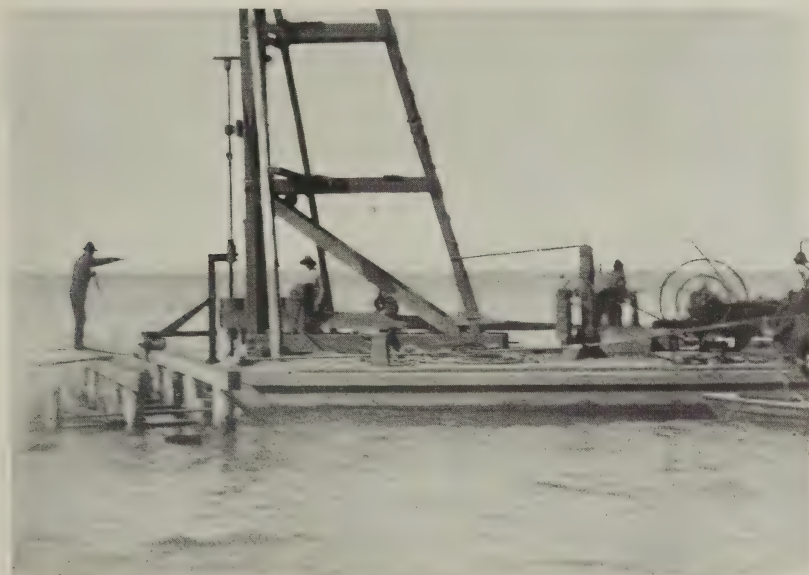


Fig. 1. Showing the guide bracket in use.

seen from the drawing that the bracket when its wheels rest on the cap fixes with great exactness the vertical distance between the top of cap and the saw, the elevation of the cap having been carefully determined by instrumentation from a U. S. B. M.

The shaft is rotated at a speed of 500 revolutions per minute, and the scow itself is controlled by proper lines operated from winch heads on the engine. The work is done very rapidly. With good weather and quiet water the machine has frequently cut forty-five piles per hour. The accuracy of the grade can be checked by measuring the cut off piles and only errors of a few hundredths of a foot have been discovered. Delays occur through inability to clear

away the cut off piles, for which the machine is in no way responsible.

For the operation of this machine seven men are required on the scow. Five other men are engaged in taking care of the piles as they are cut off and cutting off piles above water and placing the caps for the guide bracket.

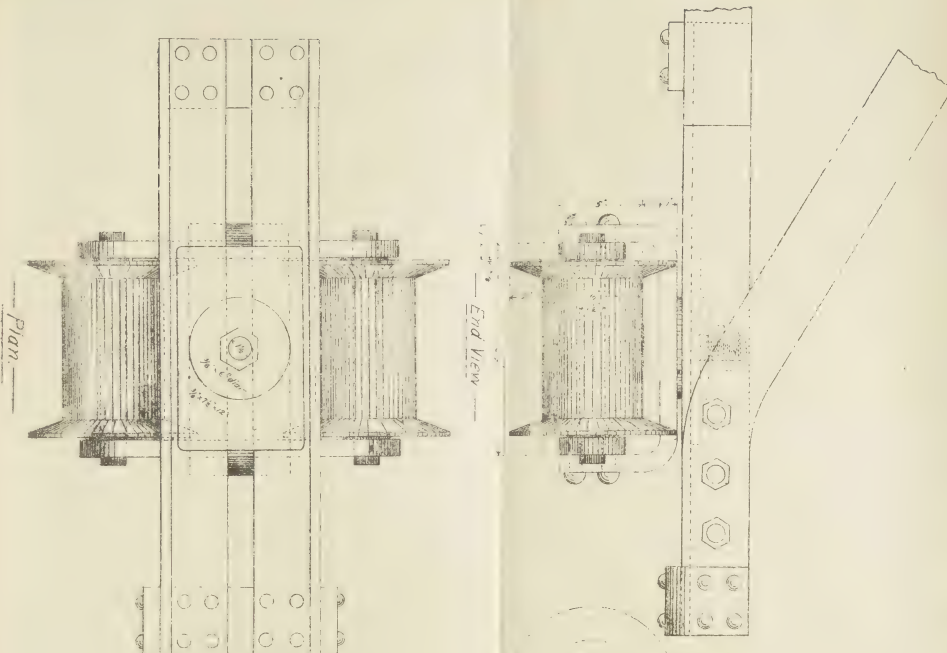
The total cost per 8-hour day for crew, fuel and oil, \$36.15. Time actually worked, 5 hours. Time worked, including transfer of machine and setting it in position, 7 hours. Number of piles cut



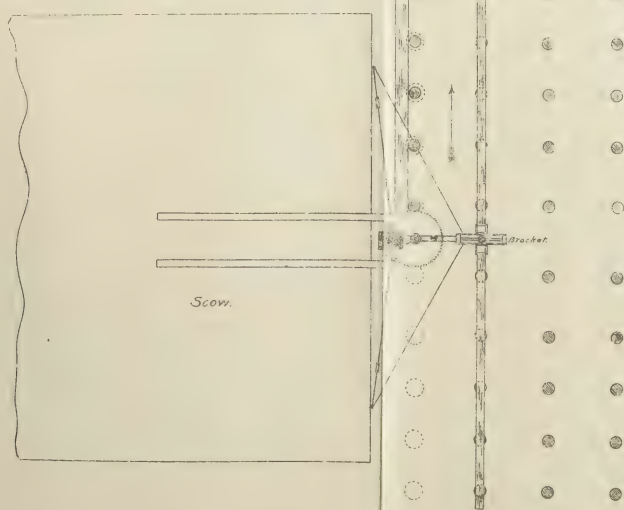
Fig. 2. Showing piles cut to grade to receive guide cap.

off, 230. Average time to cut off one pile, based on 5 hours' actual running, 1.3 minutes. Mean cost per pile at 230 piles in 7 hours, \$0.1375. Accuracy of cut off, one-fourth inch and less. On several occasions a bent containing 10 piles was cut off in 6 minutes. Diameter of piles at cut off point, from 11 to 19 inches.

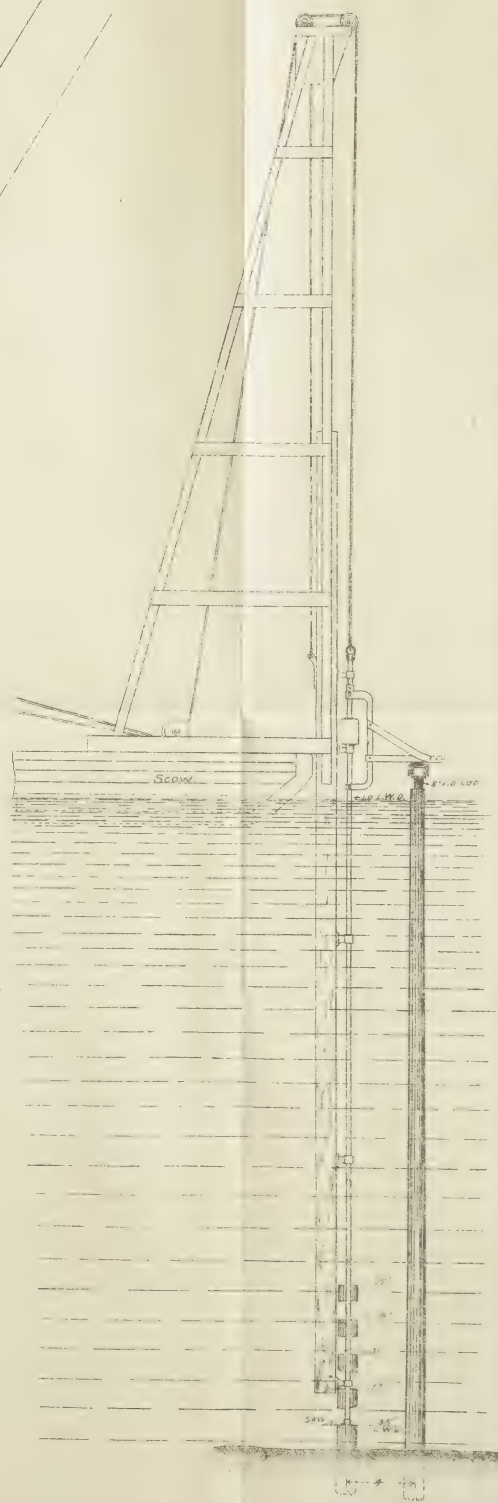
The work done by this machine could not be performed by a diver with such unerring accuracy. A day's work for a diver operating a hand saw rarely exceeds twenty piles. The average cost of a diver with his outfit in this harbor is \$40.00 per day. This would mean a cost of \$2.00 per pile as against 13.75 cents for the machine, or \$5,000.00 for cutting 2,500 piles as against \$343.75 for the same work with the machine. From the foregoing description of this machine it is easy to see that where the work to be per-



Details of guide trolley for pile
cut-off machine.
Superior Entry, Wis.
SCALE OF INCHES
0 2 4 6 8 10 12



Plan of cut-off machine while at work cutting off bearing piles.
Lateral movement of scow is controlled by lines.



General view of pile cut-off machine
showing guide bracket.

SCALE OF FEET
0 4 8 12 16 20

formed is considerable, as in this case, there can be no question of the economy of the machine, and especially is this true when great dispatch is required. With a diver it would have required one hundred and twenty-five days to complete the work as against nine days with the machine. This same machine without the bracket attachment cut off upwards of 2,000 piles for the north and south concrete revetment foundations at Superior Entry at a depth of 18 feet low water datum and was then modified for the more accurate work of the cut foundations of the breakwater heads.

For the further elucidation of this machine and its work two photographs (Figs. 1 and 2) are herewith submitted, showing it at work on the site of the breakwater head foundations. In these photographs the operation and use of the guide bracket are clearly shown.

The machine was designed and built under the direction of Col. Graham D. Fitch by Clarence Coleman, Assistant Engineer, and M. W. Lewis, Junior Engineer.

With the exception of the mandrel beam and shaft, with their accompanying devices, the machine is entirely made up of plant used for other purposes on the work; the boiler, engine, etc., being removed and used on other plant as soon as the purpose of cutting off piles has been accomplished.

LITHOGRAPHIC MAP REPRODUCTION

BY

CAPT. J. A. WOODRUFF

Corps of Engineers

For the assistance of officers of the Corps of Engineers who may have charge of the lithographic outfit which should be part of the field equipment of an engineer battalion, the following description of the process used in the Department of Engineering, Army Service Schools, for the reproduction of maps is given.

For the past two years the department has been in charge of Capt. Edwin T. Cole, Eighteenth Infantry, who was assisted in the lithographic work during the first year by Lieut. John A. Holabird, Corps of Engineers. All the work has been done on hand presses which could be used in the field.

The principal work has been the reproduction of maps for use in map problems and map maneuvers; and in the illustration of pamphlets issued by the various departments.

DIRECTIONS FOR MAKING ZINC-ETCHED LITHOGRAPH PLATES

Use polished zinc. Mirror polished zinc 16 gage as furnished for zinc etching is very good, especially for large plates which are to be used considerably.

For ordinary work No. 12 (not gage) litho zinc procured from National Steel and Copper Plate Co., Chicago or Brooklyn, is very good. This is rolled polish finish, and before coating should be polished with charcoal made in blocks for zinc polishing, to be procured from any dealer of photo-engraving supplies. This zinc is about half the weight of the 16 gage and costs 8½ cents a pound, while 16 gage polished costs 12½ cents. The charcoal leaves a soft satiny polish without scratches of perceptible depth.

With plate polished, washed and dried, coat with following:

Fifteen grains ammonium bichromate to 8 ounces water.

Beat up 1 ounce white of fresh egg to froth, then gradually pour in and beat with this the ammonium bichromate solution.

Add 10 drops stronger ammonia and 10 drops grain alcohol.

Pour this on plate and distribute like flowing collodion on wet plate.

After coating covers whole surface of plate, drain off surplus and dry plate on whirler over gentle heat applied to uncoated side. There are several types of whirlers for sale. Ours is a cross of light gas-pipe large enough to support the largest size plate used. There are holes in the pipe for studs to prevent the plate being whirled off; and the whirler is supported at center by an upright screwed to the table, and spins in a horizontal plane on this upright at center. This whirler is very effective, and can be made by any pipe fitter. Have lamp or heating gas burner under plate. Care must be taken to use this heat to dry the coating evenly and not to burn it. The plate is now light sensitive and must be used at once or kept in dark. It does no harm to keep it a short time, but it should generally be coated when needed.

Place the plate in printing frame under a glass or paper negative. Use a regular pressure frame for metal printing. A paper printing frame will not do. It is not possible to examine printing, and the amount of exposure must be learned by experience. Beginners should use a print meter. The Penrose zinc print meter is a good one.

The printed plate is rolled up dry with etching ink, using a hard composition or prepared smooth map lithograph roller. Cover the whole space occupied by design with an even coating. The amount will have to be learned, but a proper film is a dark gray. Do not try to get the film a solid, deep black. If too much ink is used, the design will smear in development. If too little, it will not hold powder.

Put the plate in a tray and cover with water. This water should be at a temperature of about 65° to 70°. With absorbent cotton, working under water, gently rub, and all ink will come off except on printed lines. This washing should be thorough but gentle. Any ink rolled up on the edges of the plate where the coating was not protected by the negative will not come off by this process. This can be readily removed by firm rubbing with a wet rag with a little pumice. Be careful not to let this get on the design, and after this rubbing, wash the plate thoroughly under a faucet and stand on edge to dry.

After the plate is dry, coat it thoroughly with etching powder. An equal mixture of top powder and dragon's-blood works very well. This powder should be in a tray or box large enough to hold

the plate. It is thoroughly dusted over the plate and gently rubbed into the lines, to which it adheres, without using pressure. See that the powder is applied to the whole design, and after coating, dust the plate thoroughly with a broad camel's-hair brush, being careful to leave no powder except on the lines. The plate is then heated, the heat being applied to the back. This fuses the powder on the lines. This heating must be carefully done, so as not to burn the powder. The fusion can be noticed by change of color and appearance of lines. The heat necessary for this fusion will warp the zinc plate. It should at once be placed on a flat surface, design side up, to cool. If this is not done, the plate after cooling can not be flattened out except by pressure and is apt to flatten by a bending at one point, thus ruining it.

After cooling, the plate should be retouched with engravers' needles and scrapers. Anything not desired on the final print can be carefully scraped off. Any line broadened by poor contact or original error in drawing, etc., can be fixed. Any breaks or omissions can be strengthened by asphaltum paint applied with fine brush. This is not the time for getting the copy correct (that should be looked to in preparing the design), but for the regular "spotting" work of all photographic printing.

The plate is now etched. For this a wooden or earthenware etching tray is needed. The etching fluid is dilute nitric acid, about one ounce commercial acid to one gallon water. An etching brush is necessary to get the metal on which the acid has acted off the plate. This etched metal is dull and tarnished and should be removed by the brush, keeping the metal surface bright. This etching is not to secure printing relief and is very gentle; as a rough estimate, as deep as the thickness of ordinary writing paper. If it is made too deep, the sides of fine lines, as the etching exposes them, are apt to be eaten away and the lines destroyed.

After etching, the plate is thoroughly washed off with running water. It is then gummed with a solution of four to six ounces of dextrine to the gallon of water and dried. It is now ready for lithographic printing, being treated the same as a stone which has been finally finished and gummed up.

In printing, the best results are obtained by using dextrine instead of gum arabic in the moistening water. In winter the moistening water has some of the dextrine solution added. In hot weather the regular dextrine solution is used for moistening.

Machine finished or S. & S. C. book papers give the best results.

Bond papers will not print on a hand press, but give excellent results on a rotary offset press. Coated book or special lithograph papers do not give good results on a hand press. The best of these adhere to zinc and have to be soaked off. If work is desired on such paper, the plate should be fanned dry after inking. With care the plate will give any number of prints on a hand press. We have printed up to 2,500. If carelessness gets grease spots on the plate, it can be saved frequently by washing out with turpentine, rolling up carefully, re-powdering, cleaning off spots with pumice, re-touching and re-etching.

When putting away the plate, gum up and dry flat and store in the rack on edge. Besides its excellent qualities for direct printing, the plate gives splendid india-paper re-transfers. Half-tones work well by this method.

Book Review

MILITARY MAP READING: *Capt. C. O. Sherrill, Corps of Engineers, U. S. A. Ketcheson Printing Co., Leavenworth, Kans.* To an engineer this book would seem a superfluous contribution to literature unless at some time in his career he had endeavored to teach the rudiments of map work to others whose education had been along entirely different lines. After one such effort at instruction, however, he will realize that any text-book on map reading must be elementary, and will recognize the usefulness and the clearness of Captain Sherrill's book. It is written for persons making the first study of the subject of map reading, and such persons will find the ordinary problems fully and clearly explained and illustrated by examples and drawings. The ability to read a map is an essential qualification for all officers who expect to rise above the command of a company, and such ambitious officers will find valuable help in this book, which will be especially valuable to officers of the National Guard who are compelled to educate themselves in military matters. This book can be obtained from the Division of Militia Affairs, Office of the Secretary of War, Washington, D. C.

W. D. C.

A COMBINED POSITION SKETCH

BY

CAPT. J. A. WOODRUFF
Corps of Engineers

The National Guard authorities of Missouri, in June, 1909, desired to have a map made of their maneuver grounds at Nevada, Mo. Being unable to get a detail from the Third Battalion of Engineers to do the work, they applied to the commandant of the Army Service Schools, and upon their agreeing to pay the necessary expenses, it was decided to have the Staff Class make the desired map.

The Staff Class, of twenty-three officers, with two instructors from the Department of Engineering, left Fort Leavenworth on the evening of June 11, and arrived at Nevada, Mo., at 7 a. m. the next day.

After breakfast the class left the railroad station in six carriages, drove to the maneuver grounds, and were deployed along the control road (Clark road, 20-11; see map). The deployment commenced at 8.30 a. m. and was completed at 9.30, by which time all the parties had commenced work.

The completed sketches commenced to come in by 2.30 p. m., and by 3.30 all the parties had turned in their sketches and the complete map was ready to blue print. The map was not printed in the field, as the necessary printing frame and paper were not taken along, but a blue print was made the next morning immediately after the return to Fort Leavenworth.

As a number of copies of the map were desired, it was traced in ink, transferred to a zinc plate, and printed in the lithographic department of the Service Schools. The transfer could have been made from the original field sketches, but the resulting map would not have been as uniform in appearance and as easy to read as it was when traced by a good draftsman.

The map was made by the system of combined position sketching, devised by Capt. E. R. Stuart, Corps of Engineers, and described

in his book on combined sketching (Individual and Combined Military Sketching, by Cole and Stuart).

The class was divided into twelve parties of two sketchers each; ten of these parties mapped the area south of the control road, each party mapping an area 3 miles long by one-half mile wide. The area north of the control road was mapped by two parties, each mapping an area 2 miles long by 1 mile broad.

Each officer was equipped with a hand plane table 13 by 14 inches, with a trough declinator having a $2\frac{1}{2}$ -inch needle, and a

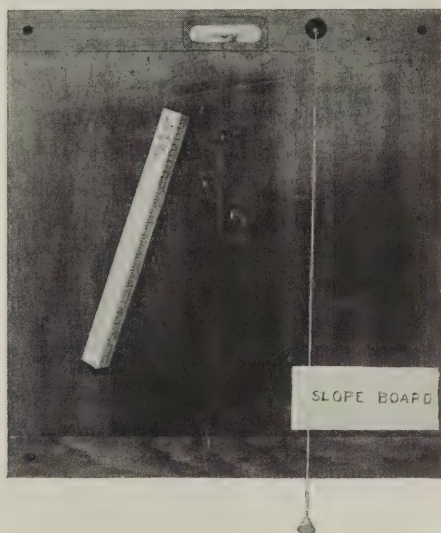


Fig. 1. Top of plane table.

loose ruler of triangular cross section. Slopes were read by the slope board attachment, and in addition each officer used an aneroid barometer to obtain differences of elevation. Distances were obtained by pacing.

The plane table used in the Service Schools for road, position and outpost sketching is shown in the accompanying views. Fig. 1 shows the top of the table, the declinator, alidade, scale for reading angles of slopes, plumb bob, recess into which it fits when not in use, and holes in the corners of the board for attaching carrying cord. Fig. 2 shows the back of the board, method of securing plumb bob when not in use, wrist strap and carrying cord, either of which may be used. Fig. 3 shows method of supporting the

board while sketching without a tripod. Fig. 4 shows how a light photographic tripod may be used. The socket for this may be used for the attachment of the wrist strap.

The map was made on a scale of 6 inches=1 mile with 10-foot contours. In order that the work would not be interfered with by rain the sketches were made on celluloid.

By a reference to the map it will be seen that all military feat-

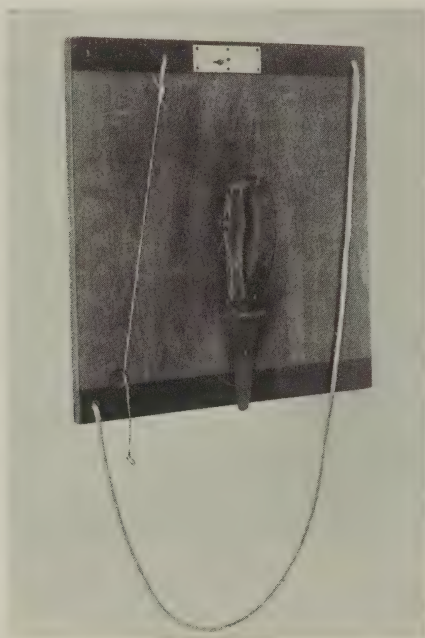


Fig. 2. Back of plane table.

ures are shown, including roads, streams, contours, woods, houses, fences, and the character of the cultivation. All cross roads and road junctions were numbered and the names of all houses noted for convenience in writing orders and locating troops by the map. This is an important detail of a military map, and one that is often omitted. In addition, names were given all the roads.

The deployment of the sketchers and the assignment of areas to the parties were indicated by cards posted at intervals of half a mile along the control road by the director of the survey who rode in the leading carriage. These cards gave the number of the party

that was to commence sketching at each point, and the elevation, obtained with an aneroid barometer.

In order that the method of making the separate sketches, so that they can be combined rapidly, may be understood, a short description will be given. The first sketcher of Party A commenced at 20 and sketched 3 miles due south along the Stringfellow road, mapping as far to the east as practicable and about one-eighth mile to



Fig. 3. Plane table without tripod.

the west. No. 2 sketcher paced the distance from 20 west to Morton lane and then joined No. 1 sketcher of Party B, who had commenced work at the intersection of Morton lane and Clark road. No. 1 sketcher, Party B, assisted by No. 2, Party A, sketched due south along Morton lane a distance of 3 miles, mapping a strip one-eighth mile on each side of the road.

When 3 miles had been mapped, the two sketchers on Morton lane cut the map along the road and the No. 2 sketcher of Party A took the eastern half and joined the No. 1 sketcher of his party on the Spencer road, one-fourth of a mile west of 23. No. 1 sketcher

of Party B took the western half and joined his No. 2 sketcher one-fourth of a mile east of 24.

The two sketchers then placed their sketches on the plane table parallel to each other and the proper distance apart, and then cut them down the center, discarding the overlapping pieces. They then sketched down the center of their area joining the contours of the sketches made on each side, and filling in the detail on the center strip one-fourth of a mile wide.

Each party then turned in the two strips which matched on the center line of their area, as they had been so made in the field, and which also matched with the sketches of the adjacent parties, as they had been cut from them.

It may be argued that without the section line roads and fences the system would not give good results. It is true that the section lines are a great aid in producing an accurate map, but the method has been repeatedly tried in country without section lines, and the resulting map has been remarkably accurate, and entirely satisfactory for a military map by which orders may be issued for the deployment and posting of troops and guns.

The lack of relief in the area mapped was a great disadvantage, as the aneroid barometer gives much better results, and contouring is easier in a terrain with considerable relief and more decided drainage lines.

It will be noticed that the map covers an area of 27 square miles, which was made in seven hours by twenty-four officers. The success of the system depends upon the work of the slowest sketchers. Many of the officers in the class knew practically nothing about sketching when they entered the Service Schools. During their first year in the Army School of the Line they had had less than fifteen days for sketching, half of which was devoted to road sketching. In their second year they had made four individual road sketches, two combined road and two combined position sketches, to each of which was devoted one day.

The front of a division in line of battle should not ordinarily exceed 3 miles. A contoured position sketch of an area of this width and of a depth of 2 or 3 miles could be made by the above method by twelve sketchers. From the battalion of engineers with the division it should not be difficult to train a detachment of that

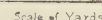
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 $V_1 = 10 \text{ ft}$ 

size, so that they could map rapidly and accurately all the terrain required for the operations of the division.

The same detachment could readily make combined road sketches for each day's march of the division. For this work Captain Stuart has devised an excellent system which is followed in the combined road sketching of the Staff Class. By this system three or more parallel roads for a 15 to 25 mile march, with all cross

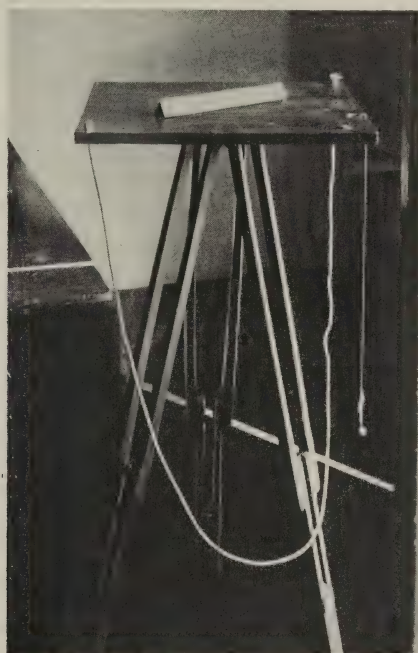


Fig. 4. Plane table on tripod.

roads and most of the country between, are mapped, the sketches combined and blue-printed within eight hours.

THE DREDGES "LEVIATHAN" AND "CORONATION"

BY

H. LEROY POTTER

Junior Engineer

While en route to England, in March, 1909, my interest was aroused by a fellow-passenger who told me that a dredge which pumped 10,000 tons per hour had just been completed for work on the Mersey.

Having received a letter of introduction to the chief engineer of the Mersey Dock and Harbor Board, I was enabled to see this dredge.

The *Leviathan* is of the twin-screw, self-propelling, hopper type, having a hopper capacity of 10,000 tons. The principal dimensions are: length, 465 feet 9 inches between perpendiculars; breadth, 69 feet moulded; depth, 30 feet 7 inches moulded.

At the time of the writer's visit, the dredge was in the dock getting ready for work. She had just finished her trial trip and no real work had been done except one load of sand pumped and a speed test made.

My first impression of her as she lay at the dock was one of admiration at the size of such a boat for dredging. I will not give a detailed description of the dredge, but will mention a few points which interested me particularly. One of the important points is the four suction tubes, two on each side of the dredge. The lead of each tube is forward and the tubes are of such a length as to permit dredging in 70 feet of water. The angle of inclination does not exceed 45 degrees below the horizontal when dredging at this depth.

I noticed that they were putting in new wire hoisting cables, 1½ inches in diameter, the ones used on the trial trip being a little too small. One of the wells had failed to dump, as the gate did not work. The dumping is done by means of hydraulic valves, operated by hydraulic cylinders, one to each valve.

They had riveted new plates on the derricks carrying the suction pipes. One of these had bent a little on the trial trip.

The dredge could work at anchor only, the idea being to pull ahead into the material, if found necessary.

They spoke of the sand pumped on the trial as not being a good Mersey bar sand. What I saw in the hopper appeared to me like very good material to pump. It was coarse enough to settle rapidly and was loose on the bottom when pumped. There were no stones or other foreign matter in the hopper. The pumps are of the balance type; that is, the intake water is divided just outside the pump and goes in on either side. They keep a small stream of water flowing just inside the pump on both sides with the idea of keeping the sand away from the bearings. The pump runners, casing and heads, are all of steel, but the pipes inside the dredge, to the pumps and from the pumps to the discharge trough in the bins, are of cast iron, 1½ inches thick. They told me that these cast iron pieces on some of the dredges had been used six years and were still good. We have not been able to use similar pieces in the Ambrose Channel dredges over two or three years.

The Mersey sand does not seem to be as sharp as the sand in the Ambrose Channel. They do not get stones, pieces of iron, shell and other material in anywhere near the quantity in which we get it. They have the steel grating on the mouth of the suction pipe, with openings about 8 by 9 inches.

I inquired particularly as to the arrangement of the outboard bearings. The tail shafts run through stern tubes, which are kept filled with oil from a small tank of about 10 gallons capacity, placed on the bulkhead, and having a head of perhaps 20 feet. There is the ordinary brass liner on the shafts, running in a sleeve filled with babbitt metal. On only one occasion after a year's wear had the shaft been down more than one-half inch. Once it was found to be down three-fourths of an inch, and I was told that this caused a big stir in the office. This, of course, was on a similar dredge.

The men running the hoisters for the suction pipes are in small houses on deck. They, themselves, can not see the suction pipes. These pipes are raised, lowered and brought inboard on signals from men on deck. It struck me that if they had so arranged the levers from the upper deck where the operator could see the pipes, it would have been better and would have done away with four tube men.

While the chutes carrying the sand and water have openings so as to discharge into any pocket, for the purpose of trimming the

dredge, the main idea is to carry the material to the forward part of the bin and then let it run back to the after part where the four overflows are located. From the height and position of these overflows it seemed to me that with any list, or in rough weather, the water would go over the coaming and onto the deck, and they told me that it did do this on the trial trip.

The quarters for the officers are aft. They are commodious and on the whole very good. They are not provided with running water or steam heat, the water for washing being brought in pitchers and the heating done by soft coal stoves. The quarters for the crew are all forward. They are comfortable, but, of course, heated with stoves, and the water for washing obtained from a pump on deck.

Around the stern is a large fender to protect the rudder and propellers when the dredge is coming in or going out of the docks, and from other boats.

There is no doubt that the dredge will be able to do what they claim for her, on the Mersey, and is well adapted for the work. Yet, in my opinion, she would not work to good advantage in New York Harbor, or in any harbor which I personally know about in the United States.

To run this dredge they have two captains and a crew of sixty men. Each shift works twelve hours. The officers are paid about one-third less than our officers. The crew get about one-sixth less than ours. They estimate a consumption of about 400 tons of soft coal per week. To run the dredge per year, including all expenses, they estimate \$160,000. I think this a liberal estimate.

They have on board a superintendent whose duties, as far I could learn, are nominal, as the captain has entire charge.

On the following day, in company with Captain McLean, dredging superintendent, I visited some of the other dredges, boats and docks of Liverpool. The dredge *Coronation* is worthy of mention. In carrying capacity she corresponds to our *Raritan* and *Navesink*. She has a steel hull built in 1903. Length between perpendiculars, 332 feet; breadth, 52.7 feet; mean draft loaded, 17.2 feet; speed about 10 knots, and carries 3,500 tons loaded. She has triple expansion main engines, 2,000 horsepower; pumping engines, 800 horsepower; three marine multi-tubular boilers carrying 180 pounds steam, two 36-inch pumps and suction pipes, 81 feet long. This dredge carries thirty men and each shift works twelve hours per day. They can work at anchor only. In most respects she is

like the *Leviathan*, only smaller. There are no overflows in the bin. The water flows over the coamings onto the deck, and so over and down the sides of the dredge. The engine room was in good condition and the pumps ran smoothly.

The officers' quarters were aft, below deck, heated with stoves and had no running water in the rooms. The crew's quarters were forward and comfortable.

The pumps were operated from the wheel house, and indicators show depth of nozzle, steam pressure and pump vacuum, on which they depend for telling whether the pumps work well or not. They have blanks which are filled out by the captain, giving data of different loads, tons in load, where pumped, time of pumping, time going to dump, dumping, returning, weather conditions, etc. These are sent to the office every day. The captain has entire charge of the dredge. The crew subsist themselves; that is, they pay for the food, but the office pays for the cooks. I was told that they could live well on \$2.50 per week per man.

They use about 150 tons of soft coal per week. They work twenty-four hours per day, and consider that they have done a good month's work if they have worked twenty-one or twenty-two days. The delays are due more to bad weather than to breakdowns. I asked them how they measured the material in the bins after they were loaded, and they showed me a gauge in the pilot-house which registered the water displaced by the dredge. From computed tables the tons in the bin were given. They did not take any soundings in the bin to verify this, although it could easily have been done.

At the present time there is only 29 feet of water over the Mersey bar, so that the *Lusitania* and *Mauretania* are often delayed several hours waiting for the tide. They hope after the *Leviathan* gets to work, to deepen the channel to 35 feet at low water.

THE DREDGE "LEVIATHAN"

BY

HORACE LEE WASHINGTON

United States Consul

The steel twin-screw sand pump hopper dredge *Leviathan* for the Mersey Docks and Harbor Board was launched on the 26th of October, 1908, from the Tranmere Works of Messrs. Cammell Laird & Co., Ltd. This is believed in engineering circles to be the greatest dredge in the world.

The dimensions are: Length, 487 feet, over all; beam, 69 feet, and depth 30 feet 7 inches, these large dimensions being necessary to give her the capacity and strength to carry her enormous load of 10,000 tons of sand.

She is provided with pumps capable of dredging this load in fifty minutes from a maximum depth of 70 feet, and her propelling machinery is to be capable of driving her, when fully loaded, at the rate of 10 knots.

She is designed to carry her full load of sand as well as bunker coal and fresh water on a mean draft of 23 feet.

The vessel is built of steel, to class 100 A-1 at Lloyds.

The vessel has a complete steel upper deck sheathed with wood, and is divided transversely into thirteen watertight bulkheads extending from keel to deck. A longitudinal center-line bulkhead divides the hoppers, pump rooms, and boiler rooms, as well as No. 2 buoyancy space on each side of the vessel. These subdivisions taken in conjunction with the watertight hopper side bulkheads divide the vessel into about thirty separate watertight compartments.

The steel hull structure has been arranged to give special strength to the vessel, in view of the great strains developed in loading and unloading her hoppers.

The propelling machinery, which is supplied by Messrs. D. Rowan & Company, of Glasgow, will be placed aft, and consists of two sets of inverted vertical triple expansion engines, each having cylinders 22½ by 37 by 61 by 45 inch stroke.

The steam will be supplied by four large single-ended boilers placed between the propelling and pumping engine rooms, and constructed for a working pressure of 180 pounds per square inch.

Watertight doors controlled from the upper deck are fitted in the machinery space bulkheads, for access from one room to another.

The hoppers are situated forward of the pumping engine rooms, and built in twelve separate compartments, six on each side the center-line bulkhead.

The side compartments adjacent to hoppers, as well as the two forward holds, are buoyancy spaces, rendered necessary for the vessel to support her weight of hull, plant, and load on the specified draft of water.

The engineers and officers are housed in the poop, and the crew in the forecastle, the master's cabin being placed in a large deck-house on the navigating bridge, with chart- and wheel-house over.

The dredging plant is supplied by Messrs. Gwynnes, Limited, London, and consists of four sets of inverted triple expansion engines, coupled direct to four centrifugal pumps connected to their respective suction tubes, two on each side of the vessel, with hydraulic sluice valves on inboard side. Each tube is 42 inches internal diameter, 90 feet long, and bolted to a heavy cast steel swivel bent at upper end, and a strong nozzle of special form at lower end. The latter is fitted with a cast steel grid to exclude material of such a size as would choke the pump. The swivel bends work in vertical slide frames riveted to the vessel's sides with trunnions to allow the suction pipes to hinge about its center and thus be raised or lowered to suit the state of tide while dredging.

The suction pipes have 45 degrees inclination when dredging at their lowest limit of 70 feet below sea level.

Each suction tube is lifted and lowered by two strongly built steel derricks, one each side of the tube, and stepped on seats at the upper deck, and complete with blocks and flexible steel wire ropes led to the drums of its respective hoisting winch. Deck slides supported by strongly built seats on deck are fitted over each slide frame to enable the suction pipe with the swivel to bend so as to be stowed inboard when not dredging.

Each deck slide has a heavy cast iron frame, and can move inboard or outboard by a worm gear. This is carefully adjusted so that it comes exactly in the same vertical plane as the slide frame

when at its extreme outboard position, to allow the suction pipe to be lowered to its working position below water level.

Each suction tube is provided with an emergency gear, so that in case of accident the suction tubes may be lifted by blocks and tackle led to the deck winches. Two of these winches are fitted under forecastle deck, and two on the poop deck. The four hoisting winches are inclosed in steel houses with glass fronts, the latter being provided so that the winchman can control and have a complete view of the derrick lifting and lowering gear. Each hoisting winch has four drums arranged in pairs, two for raising and lowering the suction pipes, and the other two for derricking in or out board.

These powerful winches are actuated by double cylinder reversing engines.

The four dredging pumps are arranged to deliver along pipes passing up through the deck into two landers, and fitted with hydraulic sluice valves where they join the same.

The landers are built side by side with a center division and run the full length of the hoppers.

Two lander valves worked by worm gear are fitted over each hopper on the bottom of the landers so that the discharge to any hopper can be controlled as desired. By these means the valves with their control gear are also arranged within the steel division separating the two landers. The discharge of sand and water from any or all of the pumps can be controlled so as to trim the vessel as desired.

Flushing pipes with valves controlled from the fore and aft gangways are led from the lower sides of the landers for flushing each hopper when discharging the load.

Each of the twelve hoppers is fitted with Lyster's patent valves, having an opening 5 feet 6 inches diameter through the bottom of the vessel. The hopper bottom plating has a steep slope in the four directions down to the edges of the valve seat bottom casting for a quick discharge of the sand. Each valve is of a tapered cylindrical form extending the full depth of the hopper, with an opened bottom valve at its lower end and having a lift of 4 feet. These valves are worked by hydraulic cylinders controlled from the fore and aft gangways, and supported by a continuous fore and aft girder running the full length of the hoppers and above the same. Guide rings efficiently stayed to the hopper sides are fitted at the upper and lower parts of the valves for steadying the same.

A surface valve with a lever for opening or closing it from the gangways is fitted on top of each hopper valve to drain off the surface water. During the dredging operations, the mixture of sand and water is delivered into the landers and thence falls into the hoppers through the valves already mentioned. The sand settles into the hoppers while the surface water runs aft along the waterway formed of the hopper coamings to weir plates, which can be adjusted to suit the trim of the ship, and thence overboard through large rectangular chutes, two on each side. When discharging spoil, the hopper valves are raised and the sand falls rapidly through the openings in the bottom of the vessel.

An indicator is fitted up in the chart-room to show the draft of the vessel, as well as a complete system of repeating telegraphs and voice pipes for giving orders to the propelling and pumping engine rooms, and to the different winchmen.

Powerful electric alarm bells are fitted in the pipemen's positions. Pushes are fitted for each pipeman, and one on the navigating bridge so as to give alarm in case of necessity.

The hydraulic installation is provided by the builders, and consists of a set of three-cylinder inverted high pressure direct acting engines, having three cranks and three single acting ram pumps driven direct from the piston rod crossheads. The hydraulic pressure is 800 pounds per square inch, and is used for working the four main sluice valves on the suction pipe at the side of the vessel, and those on the delivery pipes at the ends of the landers, as well as for opening and closing the twelve hopper discharge valves.

The vessel is fitted throughout by the builders with a complete installation of electric lights on the incandescent system. The engine and dynamo are placed in the propelling engine room. The engine is of the enclosed type, compound direct double acting, and coupled direct to the dynamo, which is of the direct current compound type. Two powerful steam windlasses of Harfield's make, each driven by separate vertical engines, and connected by compound positive clutches at both crank and main shafts, are to be fitted on the forecastle head for working the anchors.

The steam steering engine of Caldwell's make is placed in the engine casing, and is of the combined steam and hand type, with control shafting to the steering standard on the navigating bridge. Hand screw steering gear of Hastie's make is fitted aft immediately over the rudder head for use in case of the steam gear's breaking down.

A motor launch is fitted on the starboard side, under Welin patent bow davits, for ready use when sounding or taking observations.

The vessel was superintended during construction by the staff of the engineer in chief for the Mersey Docks and Harbor Board, A. G. Lyster, esq., M. L. C. E., as well as Lloyds' surveyor.

The above particulars as to the *Leviathan* were furnished by Mr. Lyster, the designer of the vessel.

Louis Le Bèque Du Portail

Louis Le Beque Du Portail, whose portrait appeared as the frontispiece of our October-December number, was born in 1736 and was educated at a military school in France, entering the engineer service. When Franklin and Deane were in France, and were empowered by Congress to engage French officers for the colonial service, Du Portail was one of the four chosen by them; and on arriving in this country was commissioned colonel of engineers. The details of his services are not given by the historians or biographers, but these must have been important, as on November 17, 1777, he was promoted to brigadier-general, and to major-general November 16, 1781. He was with Washington at the battle of Monmouth, and a bas-relief figure of Du Portail, designed by Kelley, is on the Monmouth monument. At the siege of Yorktown General Du Portail directed the engineering operations, and Washington specially mentioned him, after the surrender of Cornwallis, in his dispatches to Congress. Du Portail returned to France after the war, and in 1782 was made a field-marshal. On November 16, 1790, he was appointed Minister of War. He was a warm and personal friend of Lafayette, and when the latter came under the popular displeasure, and his downfall occurred, Du Portail fell with him and resigned his position. After two years spent in America, he sailed on his return home in 1802, but died on the voyage. Du Portail was a notable and brilliant officer.—*Abstract from National Cyclopaedia of American Biography.*

DREDGING THE QUEENS AND CROSBY CHANNELS

BY

HORACE LEE WASHINGTON

United States Consul

The quantity of sand removed from the bar and shoals in the Queen's and Crosby Channels, leading into the River Mersey, during the year ending July 1, 1909:

	Bar.	Queen's Chan- nel.	Crosby Chan- nel.	Total.
	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>
<i>Leviathan*</i> -----	802,150	1,965,300	387,150	3,154,600
<i>Coronation</i> -----	476,800	335,800	319,900	1,132,580
<i>G. B. Crow</i> -----	1,179,000	1,689,000	1,734,000	4,602,000
<i>Brancker</i> -----	908,000	1,199,800	967,400	3,075,200
<i>No. 16†</i> -----	30,400	148,000	95,200	273,600
Total -----	3,396,350	5,337,980	3,503,650	12,237,980

*Only commenced work in March, 1909.

†*No. 16* commenced work in April, 1909.

The quantity of sand removed from the bar since the commencement of dredging there in 1890 is 40,054,590 tons, and from the shoals in Queen's Channel and Crosby Channel 93,607,860 tons, making a total of 133,662,450 tons.

The condition of the bar has materially improved since the report of last year. Recent soundings show an improvement in the general depth of the channel there as compared with the previous best condition. There is a considerable width on the south side of the channel throughout its length in which the least depth is 30 feet at low water equinoctial spring tides; on the north side the water shoals to 27 feet close up to the line of buoys; while elsewhere, with the exception of two soundings of 29 feet, the minimum depth is 30 feet.

In the Queen's Channel the dredging which has been done eastward of the Formby ship has resulted in considerably increased depth, the last survey showing a channel about 800 feet wide without any soundings less than 29 feet, and this, over space, where, at the beginning of the year, there were depths as little as 25 feet.

NOTES ON THE CONSTRUCTION OF A CONCRETE DAM AT MCGREW SHOALS, ALA.

BY

MAJ. HENRY JERVEY
Corps of Engineers

McGrew Shoals is on the Tombigbee River, 111 miles above Mobile and about 66 miles above the junction of the Alabama and Tombigbee rivers. It is the site of lock and dam No. 1 of the Black Warrior, Warrior and Tombigbee river system, constructed here to overcome the first serious obstacle to low water navigation as you ascend the river. The object of this slackwater improvement is to provide a 6-foot navigation at low water, while at the high stages, as soon as the river covers the lock walls, all traffic is intended to pass over the dams. On a rising river, before the lower pools have filled and the slope of the river become adjusted, there is a heavy fall at the crest of each dam, even when there is sufficient depth of water on the crest for the usual river craft.

The dams are therefore designed as long spillways extending well into the abutment side of the river to partially compensate for the area of cross section occupied by the lock and to permit the river as free a discharge as under the original conditions. In order that boats may use the lock until it is safe to pass over the dam, an ample guard of from 11 to 15 feet is given to the lock walls.

At the lock and dam in question the original low water width of the river was 450 feet. The lock with a chamber 52 feet wide is built on the left bank and the dam or spillway is 500 feet long. The elevation of the dam crest is 11 feet above Mobile Datum; the elevation of the top of the lock walls is 22 feet, the guard therefore being 11 feet. Under these conditions it is found that there is a swift current over the dam even for stages above 22 feet (the top of the lock walls), and while navigation is not seriously hindered at present, river steamers have had some difficulty in ascending the stream at this point. As more trouble may be experienced by towboats and fleets of barges (which in the future may navigate the river), certain current observations were taken at this dam



Fig. 1. Lock No. 1, Tombigbee River, Ala. Dam and abutment.

during the high water season just passed, in order to determine the velocity and direction of the currents at different stages of the river and their probable effect upon navigation. It is known that prior to the beginning of the improvement there was a swift current at McGrew Shoals, but no data as to its exact velocity can be obtained. The recent observations were made over a distance about the length of the lock, and at intervals of about 50 feet across the river. The results are tabulated below, but must be regarded as rough approximations:

Table I.

Date.	Stage of river above Mobile Datum.		Mean low water referred to Mobile Datum.		Over dam—current in miles.		Approximate, location of minimum current.
	Upper pool.	Lower pool.	Upper pool.	Lower pool.	Max. per hour.	Min. per hour.	
March 20, 1909	32.5 River rising 0.3 feet per day.	-----	12.0	2.2	6.0	3.1	525 feet from axis of lock.
April 8, 1909	28.0 River falling 2.0 feet per day.	-----	12.0	2.2	5.85	3.6	100 feet from axis of lock.
April 14, 1909	23.1 River on stand.	22.3	12.0	2.2	5.95	4.9	300 feet from axis of lock.

The hydrographs or daily gauge readings of the river for the calendar years 1907 and 1908, and part of 1909, accompanying these notes, show the effect of the restraint of the river by the cofferdams and dam at McGrew Shoals, and also indicate the number of days during a year when the lock is submerged and boats have to go over the dam.

The hydrographs are also interesting in connection with the construction work on the abutment and dam, which have recently been completed by the United States, using day labor and plant and appliances owned by the Government.

The lock walls were finished in the fall of 1899, but funds for continuing the work did not become available until about seven years later. Practically the three working seasons of 1906, 1907 and 1908 were required to build the dam and abutment, erect the lock gates and complete the protection of the banks and excavation of the approaches.

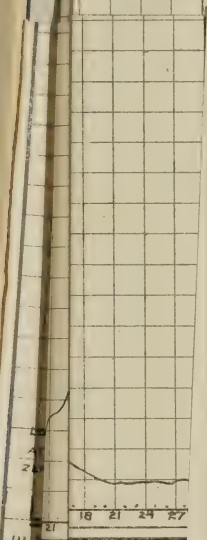
The working season, coincident with the low water season, is generally from July 1 to December 1 of each year.

About half the river was blocked by the cofferdam and dam in

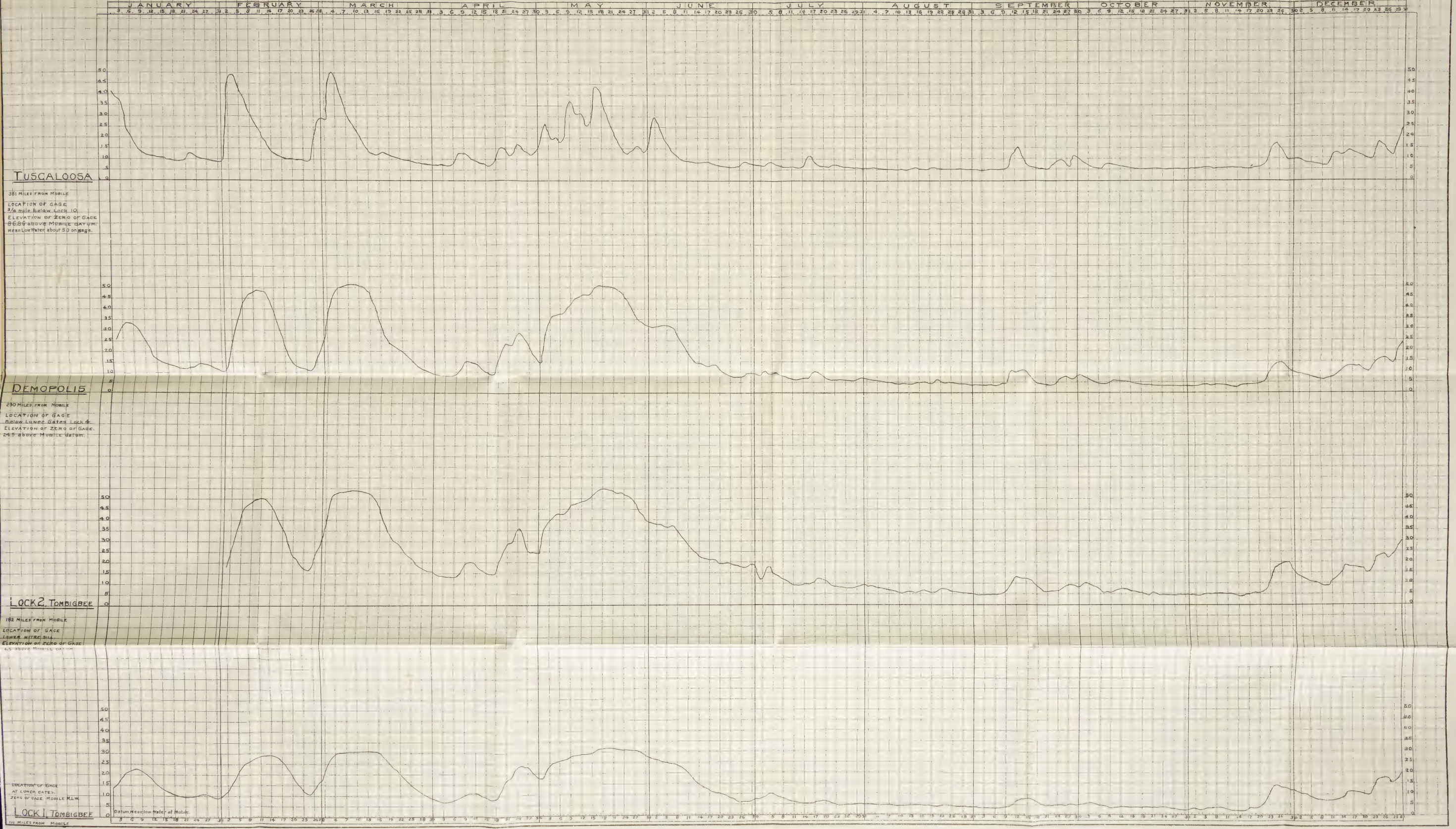
7.

EMBER

B 21 24 27 30



DAILY RIVER HYDROGRAPHS 1907.



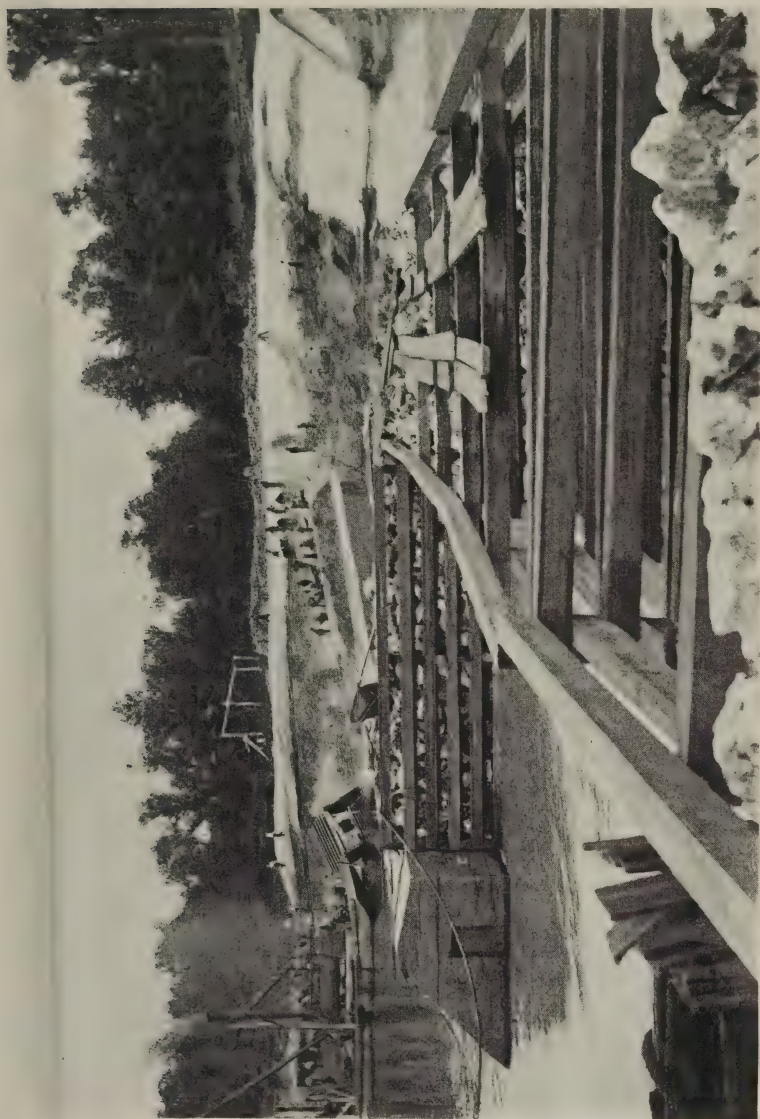


Fig. 2. Lock No. 1, Tombigbee River, Ala. Abutment, part of dam, and approach.

1907. The other half was completely closed by the cofferdam on September 6, 1908, and the lock put into service at once, there being no delay to navigation. The final closure in the concrete dam was made November 18, 1908. On December 9 the river started to rise, reaching 17 feet on the 14th.

Table II.

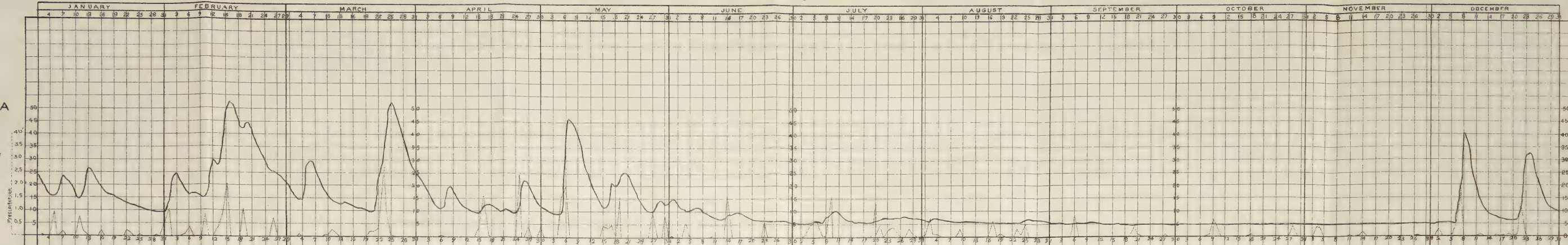
Items.	Season of 1906.	Season of 1907.	Season of 1908.	Total.
Earth excavation and filling . . . cu. yds. . .	31,655	27,819	31,798	91,272
Rock excavation cu. yds. . .		623	366	989
Clearing and grubbing acres . .	6			6
Stone delivered and stored . . . cu. yds. . .	3,807			3,807
Stone placed cu. yds. . .	813	417	6,648	7,878
Lumber delivered ft. b. m. . .	68,826	165,894	121,193	355,913
Lumber placed ft. b. m. . .	15,232	155,590	169,199	340,021
Round timber delivered pieces .	917			917
Cement delivered and stored . . . bbls. . .	1,200	5,000	2,060	8,260
Drain pipe delivered lin. ft. . .	110			110
Drain pipe laid lin. ft. . .		105		105
Artesian well lin. ft. . .	1,012			1,012
Concrete cu. yds. . .		3,663	2,644	6,307
Closure of dam November 18, 1908.				
Gravel filling cu. yds . .		160	2,031	2,191
Gates:				
Upper gates assembled in place November, 1906.				
Erection of gates and valves completed August 20, 1907.				
Actual days of work, July 1-December 31 .	130	126	120	376
Times work was interrupted by floods, July 1-December 31.	4	2	3	9
Days river was too high to work, July 1-December 31.	20	43	36	99
Days lost account of holidays and rain . .	23	18	18	59

The condition of the project June 30, 1909, and interesting details as to the locks and dams completed or under construction, are given in tabulated form in Table 3.

DAILY RIVER HYDROGRAPHS FOR 1908. BLACK WARRIOR AND TOMBIGBEE RIVERS, ALA.

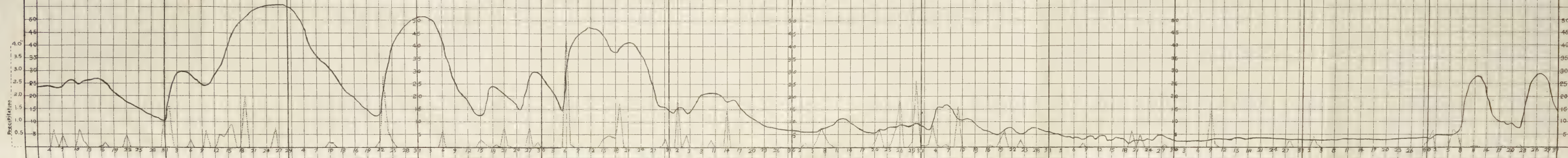
TUSCALOOSA

361 Miles.
(above Mobile)
Elevation of Zero
86.86 above M.L.W. Mobile



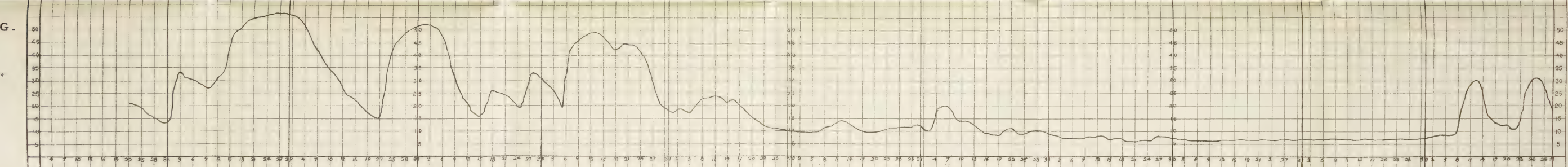
DEMOPOLIS

LOCK No 4.
231 miles
Elevation of Zero
28.70 above M.L.W. Mobile



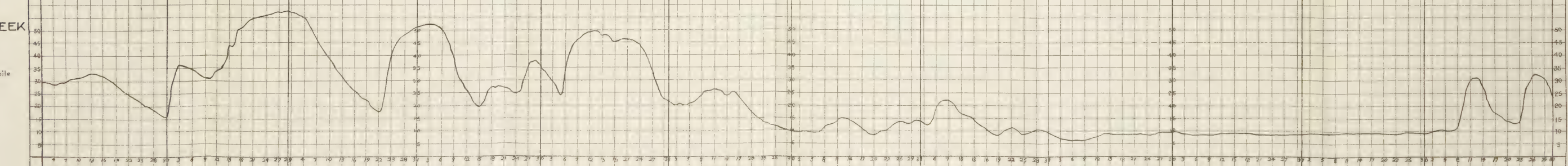
GRIFFIN LDG.

LOCK No 3.
204 miles
Elevation of Zero
14.5 above M.L.W. Mobile



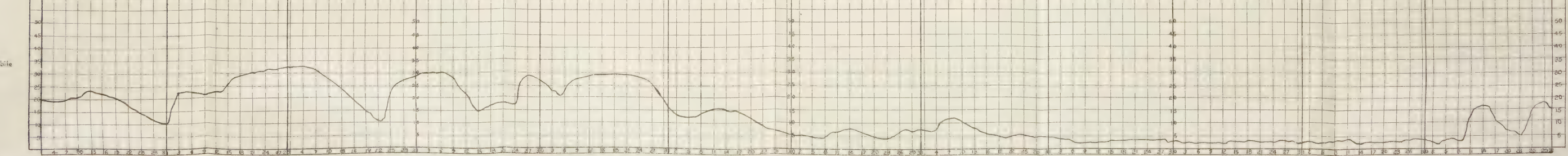
CLEAR CREEK

LOCK No 2.
182 miles
Elevation of Zero
4.5 above M.L.W. Mobile



McGREW

LOCK No 1.
111 miles
Elevation of Zero
Mean Low Water Mobile



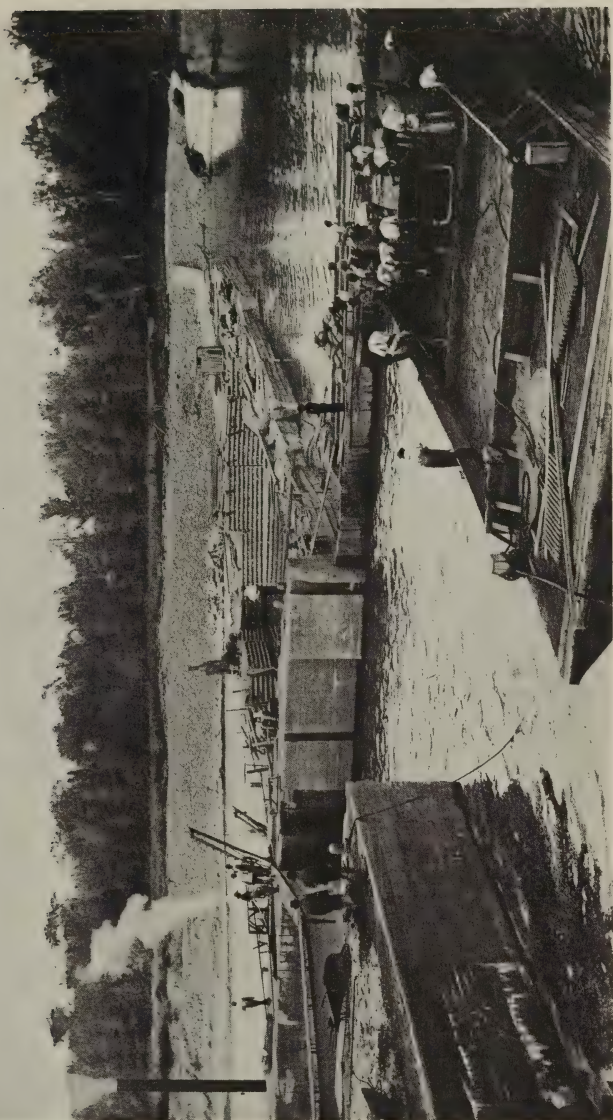


Fig. 3. Lock No. 1, Tombigbee River, Ala. View of cofferdam from lock side.

Table III.

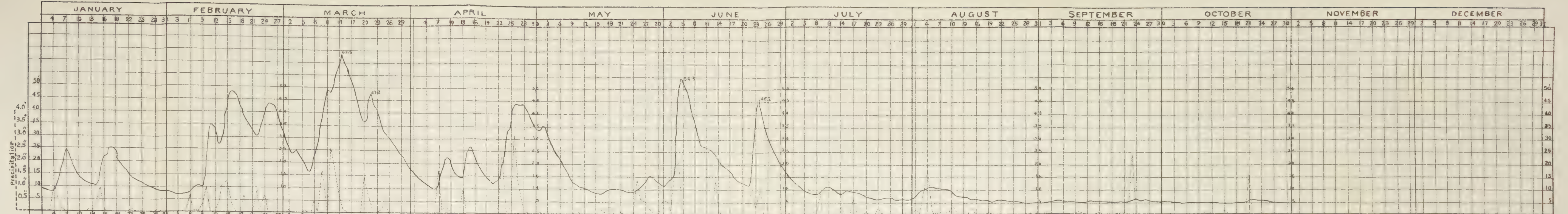
DATA IN REGARD TO LOCKS AND DAMS ON BLACK WARRIOR, WARRIOR AND TOMBIGBEE RIVERS, ALA. & MISS.																		
No.	Name of lock or dam	Elevation referred to Mobile datum				Guard at ATMLW: Lock	Gate reading at lock Dam bottom, average				Number of valves	Dimensions of each valve opening		Time required to fill chamber empty chamber	Dimensions of lock chamber		Condition of the Work June 30th, 1908.	
		Water Sill	Top of dam	Zero of dam	Zero of lock		On rising river	On falling river	filling	emptying		filling	emptying		Width	Length Between piers Available for boats		
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Minutes	9 minutes	52'	322'	
1	1110.0 MCGREW	-6.5	+3	11.0	0.0	0.0	4.5	2.0	2.0	19.1	2.0	4	6	26' x 5'	26' x 6'	52'	322'	Completed. In good condition.
2	182.0 CHENOKEL	4.5	13.0	21.0	14.5	13'						6	6	26' x 5'	26' x 6'	52'	322'	Under contract. 16 % complete.
3	205.0 GRIFTING	14.5	23.0	31.0	14.5	20.5						6	6	26' x 5'	26' x 6'	52'	322'	Under contract. 16 % complete.
4	230.6 BROWN HILL	24.5	33.0	41.0	24.5	27.0	41.0	28.5	29.0	27.5	28.0	6	6	26' x 5'	26' x 6'	52'	322'	Under contract. 16 % complete.
5	246.2 DUNN LANE	34.5	43.0	51.0	34.5	41.5	51.5	27.5	28.0	23.0	23.3	6	6	26' x 5'	26' x 6'	52'	322'	Completed. In good condition.
6	266.7 BAYVIEW DRIVE	44.5	53.0	61.0	44.5	51.5	61.5	27.5	28.0	23.0	23.3	6	6	26' x 5'	26' x 6'	52'	322'	"
7	282.3 PETERS BAR	54.5	63.0	71.0	54.5	61.5	71.4	27.5	28.0	23.0	23.3	4	4	26' x 5'	26' x 6'	52'	322'	"
8	298.3 LEE SHOAL	64.5	73.0	81.0	64.5	71.5	81.4	27.5	28.0	23.0	23.3	4	4	26' x 5'	26' x 6'	52'	322'	"
9	315.2 MILES BAR	74.5	83.0	91.0	74.5	81.5	91.4	27.5	28.0	23.0	23.3	4	4	26' x 5'	26' x 6'	52'	322'	"
10	361.9 PULASKI	84.5	93.0	101.0	84.5	91.5	101.4	26.5	27.0	23.0	23.3	4	4	26' x 5'	26' x 6'	52'	322'	"
11	362.2 TULLOCH	94.5	103.0	111.0	94.5	101.5	111.4	26.5	27.0	23.0	23.3	4	4	26' x 5'	26' x 6'	52'	322'	"
12	363.0 UNIVERSITY FALLS	104.5	113.0	121.0	104.5	111.5	121.4	27.8	28.3	25.0	25.4	4	4	26' x 5'	26' x 6'	52'	322'	"
13	370.1 WOODS SHOAL	114.5	123.0	131.0	114.5	121.5	131.4	27.8	28.3	25.0	25.4	4	4	26' x 5'	26' x 6'	52'	322'	"
14	373.5 MARSH SHOAL	124.5	133.0	141.0	124.5	131.5	141.4	27.8	28.3	25.0	25.4	4	4	26' x 5'	26' x 6'	52'	322'	"
15	380.2 ROSE SHOAL	134.5	143.0	151.0	134.5	141.5	151.4	27.8	28.3	25.0	25.4	4	4	26' x 5'	26' x 6'	52'	322'	Under contract. 55 % complete.
16	386.5 BROWN SHOAL	144.5	153.0	161.0	144.5	151.5	161.4	27.8	28.3	25.0	25.4	4	4	26' x 5'	26' x 6'	52'	322'	"
17	388.0 BROWN SHOAL	154.5	163.0	171.0	154.5	161.5	171.4	27.8	28.3	25.0	25.4	4	4	26' x 5'	26' x 6'	52'	322'	Under contract
18	398.0 BROWN SHOAL	164.5	173.0	181.0	164.5	171.5	181.4	27.8	28.3	25.0	25.4	4	4	26' x 5'	26' x 6'	52'	322'	"
19	407.6 FORD SHOAL	174.5	183.0	191.0	174.5	181.5	191.4	27.8	28.3	25.0	25.4	4	4	26' x 5'	26' x 6'	52'	322'	"

Date		Description		Amount	
Jan 1		Balance		100.00	
Jan 2		Jan 1		100.00	
Jan 3		Jan 2		100.00	
Jan 4		Jan 3		100.00	
Jan 5		Jan 4		100.00	
Jan 6		Jan 5		100.00	
Jan 7		Jan 6		100.00	
Jan 8		Jan 7		100.00	
Jan 9		Jan 8		100.00	
Jan 10		Jan 9		100.00	
Jan 11		Jan 10		100.00	
Jan 12		Jan 11		100.00	
Jan 13		Jan 12		100.00	
Jan 14		Jan 13		100.00	
Jan 15		Jan 14		100.00	
Jan 16		Jan 15		100.00	
Jan 17		Jan 16		100.00	
Jan 18		Jan 17		100.00	
Jan 19		Jan 18		100.00	
Jan 20		Jan 19		100.00	
Jan 21		Jan 20		100.00	
Jan 22		Jan 21		100.00	
Jan 23		Jan 22		100.00	
Jan 24		Jan 23		100.00	
Jan 25		Jan 24		100.00	
Jan 26		Jan 25		100.00	
Jan 27		Jan 26		100.00	
Jan 28		Jan 27		100.00	
Jan 29		Jan 28		100.00	
Jan 30		Jan 29		100.00	
Jan 31		Jan 30		100.00	
Feb 1		Jan 31		100.00	
Feb 2		Feb 1		100.00	
Feb 3		Feb 2		100.00	
Feb 4		Feb 3		100.00	
Feb 5		Feb 4		100.00	
Feb 6		Feb 5		100.00	
Feb 7		Feb 6		100.00	
Feb 8		Feb 7		100.00	
Feb 9		Feb 8		100.00	
Feb 10		Feb 9		100.00	
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Feb 17		Feb 16		100.00	
Feb 18		Feb 17		100.00	
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Feb 22		Feb 21		100.00	
Feb 23		Feb 22		100.00	
Feb 24		Feb 23		100.00	
Feb 25		Feb 24		100.00	
Feb 26		Feb 25		100.00	
Feb 27		Feb 26		100.00	
Feb 28		Feb 27		100.00	
Feb 29		Feb 28		100.00	
Mar 1		Feb 29		100.00	
Mar 2		Mar 1		100.00	
Mar 3		Mar 2		100.00	
Mar 4		Mar 3		100.00	
Mar 5		Mar 4		100.00	
Mar 6		Mar 5		100.00	
Mar 7		Mar 6		100.00	
Mar 8		Mar 7		100.00	
Mar 9		Mar 8		100.00	
Mar 10		Mar 9		100.00	
Mar 11		Mar 10		100.00	
Mar 12		Mar 11		100.00	
Mar 13		Mar 12		100.00	
Mar 14		Mar 13		100.00	
Mar 15		Mar 14		100.00	
Mar 16		Mar 15		100.00	
Mar 17		Mar 16		100.00	
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Apr 17		Apr 16		100.00	
Apr 18		Apr 17		100.00	
Apr 19		Apr 18		100.00	
Apr 20		Apr 19		100.00	
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Apr 23		Apr 22		100.00	
Apr 24		Apr 23		100.00	
Apr 25		Apr 24		100.00	
Apr 26		Apr 25		100.00	
Apr 27		Apr 26		100.00	
Apr 28		Apr 27		100.00	
Apr 29		Apr 28		100.00	
Apr 30		Apr 29		100.00	
May 1		Apr 30		100.00	
May 2		May 1		100.00	
May 3		May 2		100.00	
May 4		May 3		100.00	
May 5		May 4		100.00	
May 6		May 5		100.00	
May 7		May 6		100.00	
May 8		May 7		100.00	
May 9		May 8		100.00	
May 10		May 9		100.00	
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Oct 1		Sep 31		100.0	

DAILY HYDROGRAPHS OF TOMBIGBEE AND BLACK WARRIOR RIVERS ALA., FOR THE YEAR 1909.

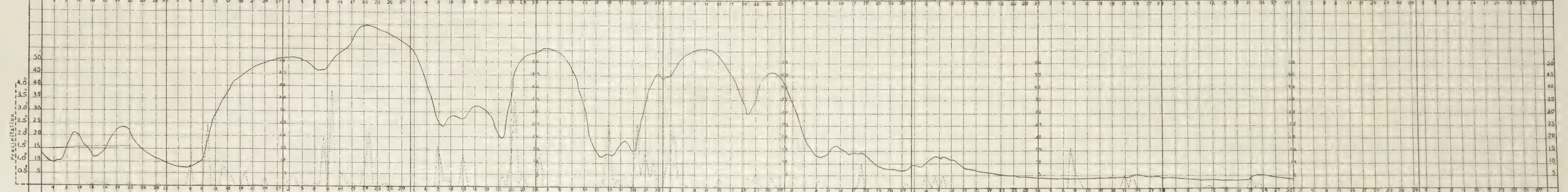
TUSCALOOSA

361 Miles
(above Mobile)
Elevation of Zero
86.86 above M.L.W. Mobile



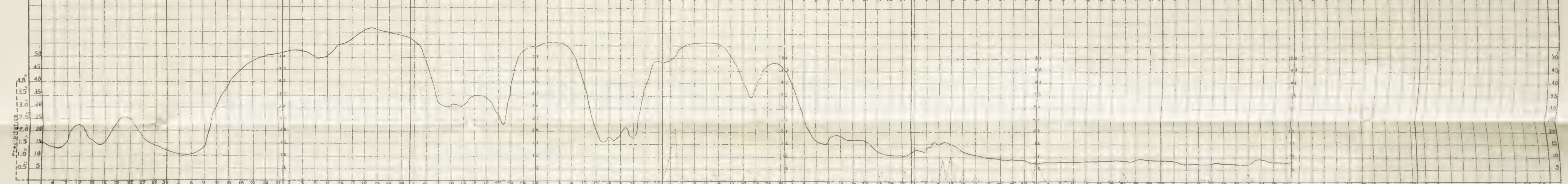
DEMOPOLIS

LOCK No 4
231 miles
Elevation of Zero
287.0 above M.L.W. Mobile



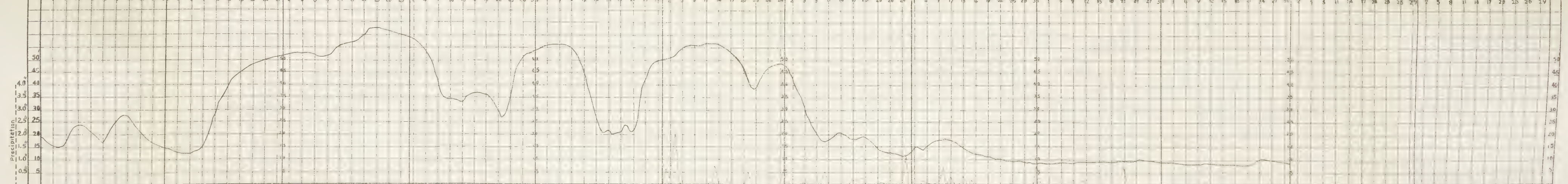
GRIFFIN LDG.

LOCK No 3
204 miles
Elevation of Zero
1450 above M.L.W. Mobile



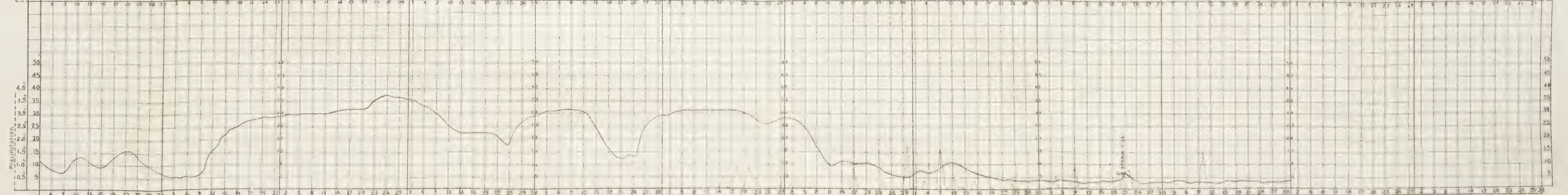
CLEAR CREEK

LOCK No 2
182 miles
Elevation of Zero
4.50 above M.L.W. Mobile



MCGREW

LOCK No 1
111 miles
Elevation of Zero
Mean Low Water Mobile



THE ARMY ENGINEER AND RIVER IMPROVEMENT*

BY

J. M. DICKINSON

Secretary of War

A native of, having passed all my life in, the Mississippi Valley, and all I possess being there, it would be contrary to human nature if I were not a zealous advocate of everything that really tends to increase its prosperity and develop its resources to their fullest capacity. I speak, therefore, as an interested individual, and in no sense as an official.

The War Department only executes the will of the people when expressed in legislative form. Its functions have no bearing upon initiating or controlling legislation, except in so far as data ascertained, and expert opinions given, by its engineers, may aid those who are charged with the responsibility of, or those who influence, legislative action. The powers and duties of the army engineers are fixed by Congress, and they are prohibited from making original investigations or recommending new projects or schemes of improvement. The proposed improvements to navigation that now absorb our interest are of stupendous magnitude, and present questions involved in much controversy. Heretofore the work has been detached, spasmodic, intermittent. It has largely depended upon the activity of merely local influences. Now all the forces of public sentiment in the states bordering on the Mississippi and its tributaries have converged, and there is a conclamatory cry for inaugurating and carrying to a prompt execution a comprehensive and permanent plan that will give to that region the highest development that its natural transportation facilities, aided by the best engineering skill, can afford. The work is too vast and costly to be improvidently undertaken. It so vitally affects the fortunes of so large a territory that no immature plan, nor one that will not be acquiesced in by the country, should have your advocacy.

*An address delivered before the Lakes-to-the-Gulf Deep Waterway Association, at New Orleans, Monday morning, November 1, 1909.

As was said by the President, who was then Secretary of War, in his address before this Association in Chicago:

“A plan should not be adopted until fully confirmed by expert opinion and careful investigation, but when it is adopted, when its utility is made certain, then it is neither economy to the Government in the matter of expenditure nor is it a benefit to the people to delay the furnishing as rapidly as it can be economically expended, of the full amount of money needed to make the improvement a useful and completed thing.”

Hasty and unsound conclusions will be discredited by sober second thought. It would be a calamity if the magnificent enthusiasm behind this movement, which it has taken so many years to evolve and concentrate, should be a mere *brutum fulmen*, as it will be, unless the reasonings in which it finds expression carry the conviction that they are sound, and promise results commensurate with the proposed expenditure.

The Government has already devoted approximately six hundred millions for the improvement of waterways, of which two hundred and eight millions were expended in the Mississippi Valley. The advocates of the proposed Intra-Coastal Waterway from Boston to Florida, and thence to the Rio Grande, covering a distance of about 2,600 miles, connecting up navigable streams *in esse* and *in posse* of approximately 27,600 miles, are not somnolent, but in a state of the highest activity. They will be insistent for appropriations. The aggregate cost of internal improvements now advocated is estimated at about five hundred millions of dollars. Those that assure the best and surest results for the outlay will come to the front. There may be co-operation, but there will probably be rivalry for appropriations. The resolutions of the Atlantic Deeper Waterways Association, while expressing sympathy with all meritorious movements for the improvement of waterways, specifically referring to that proposed from the Lakes to the Gulf, pledges co-operation only upon a plan within reasonable limits of cost. We can carry ourselves off of our own feet by enthusiasm, but can not stampede the judgment of the country. We must meet the test of cool, critical analysis. Resolutions and assertions will not carry the day. The opinions of the unscientific, however loudly and positively proclaimed, are not going to settle a matter of such complication and gravity. We may put as much vim, snap and spiritual dynamics into our proceedings as the most vehement language can express,

but these will be useful only if they stimulate to careful bedrock investigation and the formulation of something that will appeal to the sound judgment of the country.

Mr. Bryan, in his address before you last year, said:

"You can not go beyond me. If you can speak first and tell me what you want and let me speak afterwards, I will go beyond you. They said down at St. Louis that they wanted a waterway from the Lakes to the Gulf 14 feet deep. That is not deep enough, my friends; it must be deeper than that. Governor Francis told me that they are now talking about 22 feet. I think it ought to be 23. You can not give the people too good facilities for the transportation of their merchandise. If you tell me you want to improve the Mississippi, I tell you that that is all right, I will help you to improve it just as far as you please, and make the canals as wide as you please and as deep as you please, and when you get through improving the Mississippi I will start out all alone if necessary to improve every river that empties into the Mississippi."

We have gotten beyond such superficial treatment as that of this great subject. If a 14-foot depth is necessary for the development of our commerce, if the results will be commensurate with the cost, if the traffic will move by water in a volume proportionate to the outlay, then those who are competent to demonstrate should make all this clear to unprejudiced and capable judgment. If these things are so, they should be demonstrable to a reasonable certainty. If a depth of 14 feet has no advantage over that of 9 feet, commensurate with the difference in the cost of construction and maintenance, and if this is made reasonably certain, then the people of the United States will not undertake such additional useless work, and an effort to bring about such legislation will be a waste of time and merely postpone securing that which is attainable.

These questions have been considered by a board of engineers created by authority of Congress. Three of them are from the army and two from civil life. All are experienced in Mississippi River problems. It is said by experts that it has been demonstrated that coal and iron can be carried by vessels with profit, at a rate approximately less than one-tenth of the average rate of freight per ton per mile earned by the railways of this country, provided the vessels are of large size; there is a great volume of traffic, and the waterways have practically unlimited facilities. Coal is carried from Pittsburg to New Orleans by river at less than \$2 per ton, and

sugar has been carried back at a cost of \$2.30 per ton as against a rail rate of \$6. It is said that the saving to the nation by transportation on the Great Lakes was over one hundred millions of dollars for the year 1906. The improvements projected by the New York canals are based on the expectation of reducing freights on grain to two-thirds of a mill per ton mile.

It is stated by Mr. Hill, one of the greatest living railroad authorities, that under normal business conditions the railroads are unequal to the work demanded of them, that traffic is increasing with amazing rapidity and that the capacity of the railroads is taxed to handle business that can not or will not use other routes. It is declared by leading railroad men that they are not hostile to, but, on the contrary, are ardent advocates of, waterway improvement. There is conclusive evidence that something should be done as early as practicable, on a large scale, for utilizing the transportation facilities with which nature has provided us.

Our people will undertake any expenditure that they are convinced is well justified.

In considering competition with the railroads, it must be borne in mind that it can only be sharply applied as to freight that originates and ends on waterways. Any considerable movement to or from the water involves a serious factor that increases the expense in proportion to the distance. A fact that must be dealt with is that, notwithstanding the increase of traffic and improvements of waterways, the total river traffic has steadily decreased, and few rivers are now used to anything like an approximation of their capacity.

The report of the special board of engineers makes a *prima facie* case against a depth of 14 feet. It has been reviewed by the permanent board on rivers and harbors and on the main point is approved. This is not conclusive, but the burden will have to be assumed by those who assail it. It can not be overcome by assertion or general criticism. It may be wrong. It may lead to a demand for a much greater depth. In a matter of so much moment it would be unwise to either accept or reject it, until it has passed under the most critical judgment of those competent to deal with it. Where there are such strong convictions held by so many who are deeply interested, if there is room for reasonable doubt one way or the other, there should be further investigation, if other information is needed. There is great reason for expedition, but none for precipitancy. The actual prosecution of the work so long maturing to

the point of undertaking can be suspended long enough to ascertain what is practically best and demonstrate it so that it will carry general conviction. I put in a plea, therefore, for the old motto of David Crockett, "Be sure you are right and then go ahead."

In determining upon a course of action, it is well to consider that much time may be lost in standing out now for the deeper channel, unless the arguments preponderate in its favor, and also that the work recommended in the report is of sufficient magnitude to absorb all appropriations that may, under the demand in other directions, be made for this particular line of improvements, and that all of it is a necessary preliminary to the construction of a deeper waterway if developments shall show that it is economically desirable.

I only urge sufficient deliberation and care. I have not sufficiently studied the report to justify me in forming an opinion, and I must say frankly that my training would not make my opinion of any special value.

With this *caveat*, I come to the real subject of my remarks, "The Army Engineer and River Improvement;" for whether the problem be to plan or to execute, the great value of his services must be recognized.

The pioneer engineers of this country were the military engineers, the earliest effective ones being French engineers brought over through the efforts of Benjamin Franklin, some of whom held commissions in the Royal Corps of Engineers of France. Washington in 1779 induced Congress to establish a Corps of Engineers of the Army. In this distinguished body we find the names of Thaddeus Kosciusko, Bushnell, the inventor of the first submarine boat, and L'Enfant, whose fame, for a long time obscured, has been fully rehabilitated in the recent movements for restoring and carrying out his original design for the city of Washington. A Corps of Engineers was authorized by an act of Congress in 1802, which provided that it should be stationed at West Point. This was the origin of our Military Academy. Its primary object being to train army engineers, it was from the beginning, and has always been, a school of technology. For many years it was the only school in the United States of that character. Professor Riedler of Berlin, in an educational report, says:

"Before 1840 real instruction in engineering was offered almost exclusively in the Military Academy at West Point. Up to 1840—even up to 1850—nearly all the civil engineers had received their

preparation in this school. * * * Of these (its 2,000 graduates prior to 1862), two hundred became civil engineers and about two hundred and thirty entered the military engineer corps. Among the former number are the most renowned civil engineers of the country."

The mental training and the high ideals which form its beginning and throughout its history have characterized West Point, are well described in the *Engineering News* of June 2, 1904, which says that those who will investigate will find there: first, co-ordination of courses, so as to give to each subject its due apportionment of time; second, disciplinary training that tends to make leaders of men; third, physical training that insures a long life of usefulness; fourth, moral training that puts honor above every other consideration in life.

In France a military school is the most distinguished of its technical institutions. Giving proper value, even from a commercial standpoint, to the development of character, and a high sense of honor constantly sustained by the esprit of a body set apart to itself, of which each member is a guardian of the reputation of all, too much can not be predicated of the guaranty given by such a training of the inspiration of the fame that has been maintained by such a long line of famous graduates. Not only have all our military engineers come from these graduates, but from those of them who during their four years' course have given the highest evidence of ability to meet the demands of that most exigent arm of the service. But their training for their work does not stop with the academic course. They must pursue a two years' post-graduate study in the Engineer School, and when that is completed, serve for a time with engineer troops in this country and our foreign possessions, and then as assistants to experienced officers conducting professional work. Although after this understudy they may be put in independent charge of important work requiring the highest technical knowledge, they are supervised by senior officers until they reach the grade of lieutenant-colonel, and are under the corrective eye of the Chief of Engineers and general and special boards, to whose scrutiny all technical and economical questions are subject. When in connection with this training it is considered that by rigid examination, mental and physical, they are selected from all parts of our country before appointment to the Academy, and are winnowed by a constant impartial process that admits of the survival only of the fittest, are consecrated to a career that pre-

cludes the exploitation of their abilities in personal ventures, and find their highest reward in the renown that comes to those who illustrate in their lives the motto of the Academy, "Duty, honor, country," we do not wonder that the Corps of Engineers has achieved such success and maintained a reputation for ability, devotion to duty, and integrity unsurpassed (and in my opinion unequaled) for so long a time by the rank and file of any profession or calling. With one exception, its century of history has been without a blemish.

The Corps of Engineers furnished to the Army of the Potomac three commanders, McClellan, Pope and Meade, and likewise three, Beauregard, Johnston and Lee, to the Army of Northern Virginia.

For the first half of the last century the Government had to rely upon army engineers to carry out its civil work, for they were the only available experts in the country. As time went on, and works of internal improvement were undertaken by private enterprise, a draft was made upon that body. They surveyed our western country when it was an unexplored wilderness, and laid out the routes afterwards followed by the trancontinental railways. When the era of railroad building began, West Point was the only school of technology in the country. The first half century of railroad construction depended mainly on its graduates. Not only in the United States, but in Cuba, Mexico and Russia their services were demanded. They performed for the Coast Survey in its earlier years valuable services, and from the inception of the work until now have had charge of the surveys of the Great Lakes. They have run boundary lines between States, and those between our country and Canada and Mexico. They have rendered to the Treasury Department services of the highest skill and value in the construction of public buildings and light-houses. Under their supervision were erected the wings and dome of the National Capitol, the extension of the Treasury building, the Washington Monument, the State, War and Navy building, the Library of Congress, the District of Columbia building, and the Agricultural building, now nearing completion. They built the Washington Aqueduct and Cabin John Bridge, whose stone arch exceeded in length any at that time and for many years after in existence.

But what most concerns us at present is that their main work outside of purely military construction has been in studying the problems of transportation, which is one of the most important of military considerations. The great highways of the world have

been constructed in response to military necessity. This is illustrated by the great Roman ways and the conquest of the Alps. The land grants to the Mobile and Ohio Railroad Company and to the Illinois Central Railroad Company were made to establish facilities for Government transportation from the Lakes to the Gulf. The first transcontinental railway was the direct product of Government aid, extended for the purpose of establishing as a military necessity facilities for rapid transportation to the Pacific.

The improvement of rivers and harbors has been their special province. One of the earliest works of this character was that for the harbor of St. Louis, begun by Capt. Robert E. Lee in 1838. Of *ante bellum* undertakings, nothing was more notable than the surveys of the Mississippi Delta by Humphreys and Abbot, whose report upon the hydraulics of the river is characterized by a high authority as an engineering classic and a present standard work. Nothing has circumscribed their activities in developing the potentialities of our great inland seas and rivers but the amount of the funds devoted to such work. They have not only met exigencies, but have foreseen and provided for them, not merely using proved methods, but by the creative faculty devising new ones. They have taken a wide and prescient view of the growing needs of our rapidly increasing population and developing commerce. This is illustrated by the way that the great locks at the Sault Ste. Marie have accommodated with regularity and efficiency an ever-increasing traffic. Their work along the Atlantic, the Gulf and the Pacific coasts has kept pace with the demands of an incessant expansion. The channels of Boston, New York, Philadelphia, Baltimore and Norfolk are being made adequate to the needs of the largest vessels entering them. By the use of the ocean-going dredge, they have mastered problems on our southern sandy coasts formerly insoluble, as is illustrated at Charleston, Savannah, Brunswick, Galveston and other ports.

I make no reflection upon other engineers, but looking to the conditions, the complexity of the problems, and the time required for the work, after several experiments, the conclusion was reached that the construction of the Panama Canal, the greatest single engineering work ever undertaken by a people in the history of the world, should be intrusted to the army engineers. The consensus of opinion of those who are informed justifies the wisdom of that course, a justification which is based upon demonstrated care, skill

and devotion, which gives assurance of its speedy completion under a record that will redound to the honor of the whole country.

In looking at any part of this broad land, they may with justifiable pride say, "*Si requiris monuments, circumspice.*"

With this estimate of the Corps of Engineers it is hardly necessary for me to express the belief that their services will be invaluable, not only in executing whatever work may be undertaken, but in reaching a conclusion as to what is best, looking to all the conditions.

AN EMERGENCY IN THE LIFE OF A RIVER

BY

ROBERT S. TAYLOR

*Member of the Mississippi River
Commission*

What follows is in the nature of a brief for the Mississippi River before the general court of the nation—the people and their representatives, in support of its cause pending in that great tribunal, and is, in a sense, supplemental to a brochure entitled, *The Present Aspect of the Mississippi River Problem*, issued two years ago. The many figures given in that paper will not be repeated here. This discussion will be confined to facts relating to the main trunk below Cairo. There are here two distinct interests to be served—the improvement of the channel for navigation, and the protection of the alluvial land from overflow, which will be referred to separately, beginning with the latter.

If we take into account all the facts—the area of the protected lands, their fertility, the peculiar value of their products, the cost of the work which has been done, the interests which depend upon it now, and its promise of future usefulness, we are bound to say it is the greatest and most beneficent work of reclamation ever undertaken in the world. The area of land subject to overflow in a state of nature is 29,790 square miles—equal to five-sixths of the whole State of Indiana. Its reclamation began two hundred years ago, at New Orleans, and continued slowly and painfully up river for one hundred and fifty years with only interrupted and partial success. During the Civil War the levees were practically abandoned. After its close their reconstruction was undertaken, but with such small success that great floods went through them and over them without restraint. It was only when the Mississippi River Commission was created in 1879 and the United States came to the aid of the people that real progress was made. The policy of the Commission from the first was to help those most who helped themselves most. Under this stimulus the people, as a rule, did their utmost. The grand result has been that since 1882, when the first United

States money was allotted for levees, about 232,487,000 yards of earth have been put into the embankments; \$22,562,544 expended by the Government, and a much larger sum by the people through their State and local organizations, but which can not be accurately stated, for which we have to show 1,487 miles of levees, which have withstood the floods and protected the valley with substantial completeness for ten years past. The system as it stands to-day is the result of this co-operation since 1882. The feeble little lines which existed before that date have been washed away or buried under the embankments which have been built over them. The work is just beginning to demonstrate its value. The people are alive with new hope and confidence. Railroads are threading the valley as thickly as in New England. Property values have advanced enormously. The work of surface drainage is under rapid headway. In a few years this whole area will have no waste land in it. The abandonment of the levee system is no more to be thought of than the abandonment of New York Harbor or the Panama Canal. And if it is not to be abandoned, the only sensible thing to do is to maintain it in as perfect security and permanence as possible. How is that to be accomplished?

While, as stated, the lines have been effective in holding all floods for a number of years with substantial completeness, they are not yet finished. The utmost safety and usefulness of the system will require the expenditure of a few millions of dollars and three or four years' time yet. Until that shall have been accomplished the co-operation of the General Government and the States will have to continue along the same lines as in the past.

The time is near, however, when the maintenance of the levees can be turned over to the people who live behind them. This transfer has begun already. The Upper Yazoo Levee District has maintained its own lines along its entire front of 115 miles for four years, and has expended in that time \$2,344,600. Some other districts are pretty nearly ready to go it alone likewise.

These statements have reference, however, only to the maintenance of the levees—the embankments themselves. They do not include the maintenance of the banks on which the levees stand. If the people are to take care of the levees, the Government will have to take care of the river. The caving bends work their way to the base of the levees and undermine them. It has had that habit ever since there were levees to be undermined. But the greatly increased height of the floods since they have been confined to the channel,

and the correspondingly increased height of the levees necessary to confine them have introduced a new necessity for the restraint of this bad propensity. A crevasse is always a serious disaster, but it makes a world of difference whether the water goes through with a head of 5 feet, or 15. The usual course in the past has been to retreat when a caving bend threatened a levee, and build a loop farther away from the bank, connecting with the old levee at safe points above and below. This is not difficult when the embankment is low and the ground favorable. But there are situations in which it is nearly impossible. Sometimes a threatened levee stands on a narrow strip of land between a river and a lake, so that further retreat is impossible without going around the lake, which may require many miles of new work, and involve engineering difficulties practically insurmountable. In such a case it is often good economy—sometimes absolute necessity, to arrest the advance of the caving bend by revetment of the bank. This word covers any kind of work to stop caving. On the River Rhine, in Germany, it is commonly a stone wall, or sloping pavement. On the Mississippi it is a combination of brush mattress and stone riprap. The mattress is made from willow brush woven into a fabric two or three hundred feet wide, a foot and a half thick, and a thousand feet or more in length, which is laid on the underwater surface of the bank, reaching from the low-water line to the toe of the slope. Above the low-water line the bank is graded to a flat pitch and covered with a thick riprap of loose, broken stone.

The making and placing of these huge brush mats is an art which has reached its highest development on the Mississippi River, and has attracted the attention and admiration of engineers all over the world. It has reached its present perfection as a result of over thirty years of costly effort and experiment. The main object of this paper is to point out its utility on the Mississippi River and the urgent necessity which exists at the present time for carrying it forward on a more extensive scale than heretofore.

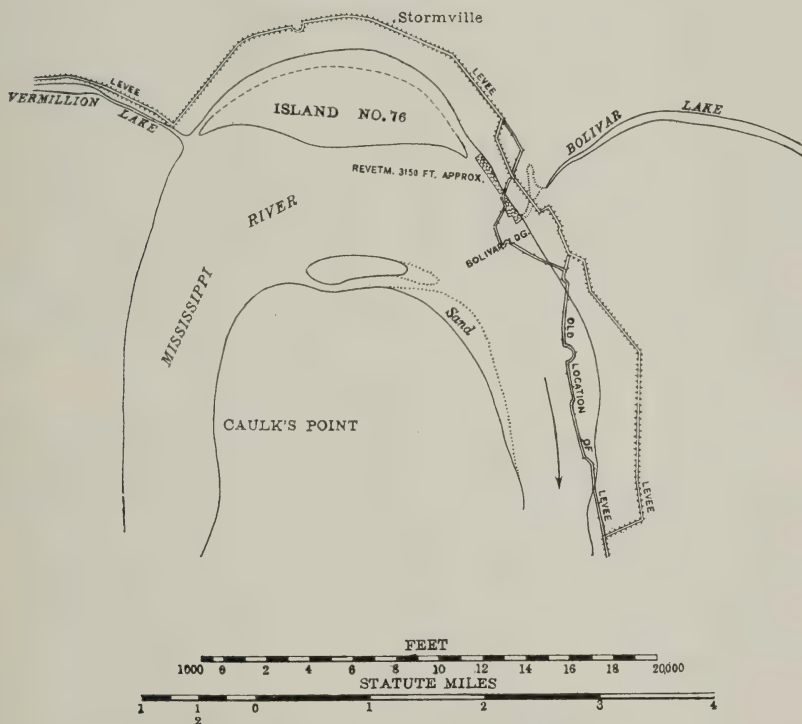
To facilitate a more vivid understanding of the facts to be presented, several maps of typical localities where revetments have been built, or are needed now, are inserted, upon which descriptions of those places will be based.

BOLIVAR REVETMENT

The first revetment built for the protection of a levee was at Bolivar Landing, in Mississippi, 418 miles below Cairo, in 1888.

The accompanying map shows the situation. The cartographers' symbols are almost self-explanatory. The double jagged line marked "levee" denotes the existing embankment; the double line with lateral, thorn-like projections at intervals denotes the location of a former levee now either undermined and washed away, or lying idle upon the bank; the unbroken black line is the present

BOLIVAR REVETMENT



river bank, and the honey-combed cross section is the revetment of brush mattress and stone riprap placed against the bank.

The levee here was a heavy, costly embankment standing on a neck only a few hundred feet wide between a rapidly caving bank and the head of Lake Bolivar. A breach at that point would have made it necessary to build a new line many miles in length around the lake and across the bayou at its foot. The revetment was undertaken as an experiment in a desperate emergency. It was a surprising success. It held the bank and has to this day. The great levee stands exactly where it stood when the first mattress was laid

twenty-one years ago. The original work has had extensive repairs and has been extended downstream about one-half of its original length. Its present effective length is about 3,150 feet.

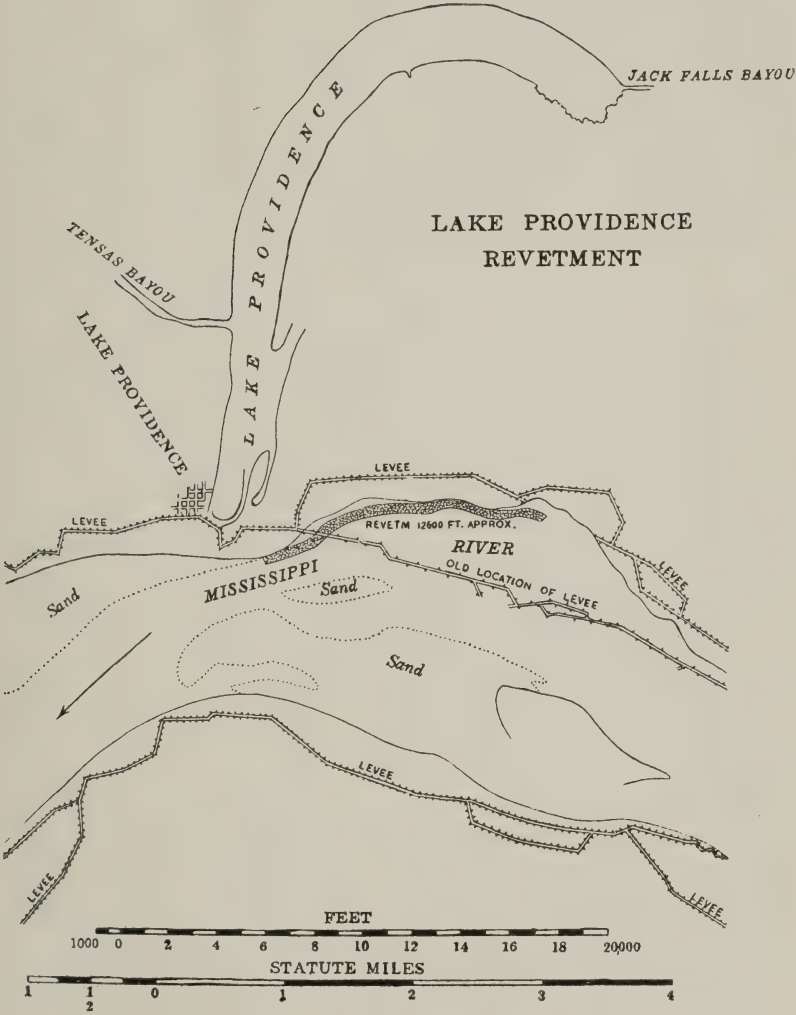
LAKE PROVIDENCE REVETMENT

A similar, but still more serious situation, developed at Lake Providence, La., 540 miles below Cairo, a map of which is inserted, which speaks for itself. The city of Lake Providence was at the head of the lake of that name, and immediately behind a levee standing on the margin of the lake within a stone's throw of which a caving bank was advancing with great rapidity. To lose the levee was to lose the city and be compelled then to build a new line around the lake and across two bayous. Encouraged by the previous success at Bolivar, work was begun here in 1894. It has had extensive repairs and upstream extensions until it is now nearly $2\frac{1}{2}$ miles long. But it has done its work well and has been a good investment. The long line of old levee location shown on the map where once stood a flood-defying embankment which has been swallowed up by the river is a grim testimonial to the relentless march of a caving bank.

ALBEMARLE BEND

These are two illustrations of successful levee protecting revetments. The map next inserted, of Albemarle Bend, in Mississippi, between Greenville and Vicksburg, shows a place where nothing has been done as yet in the way of revetment, but where something must be done without delay to avert disaster. This map goes into more detail than the others, and carries the history of the changes further back. The fine dotted lines show the location of the river in 1882, and the unbroken black lines its location at present. It appears to have crossed its own path three times since that date. The network of abandoned levee lines shows the long struggle which has been kept up to get away from the advancing bend by building loop after loop; and the lakes and bayous outside the present levee show that that struggle has reached its limit. It is now either to stop the caving by revetment, or build a new line extending far back into the country around lakes and across bayous at an enormous expense and in the face of extreme engineering difficulties.

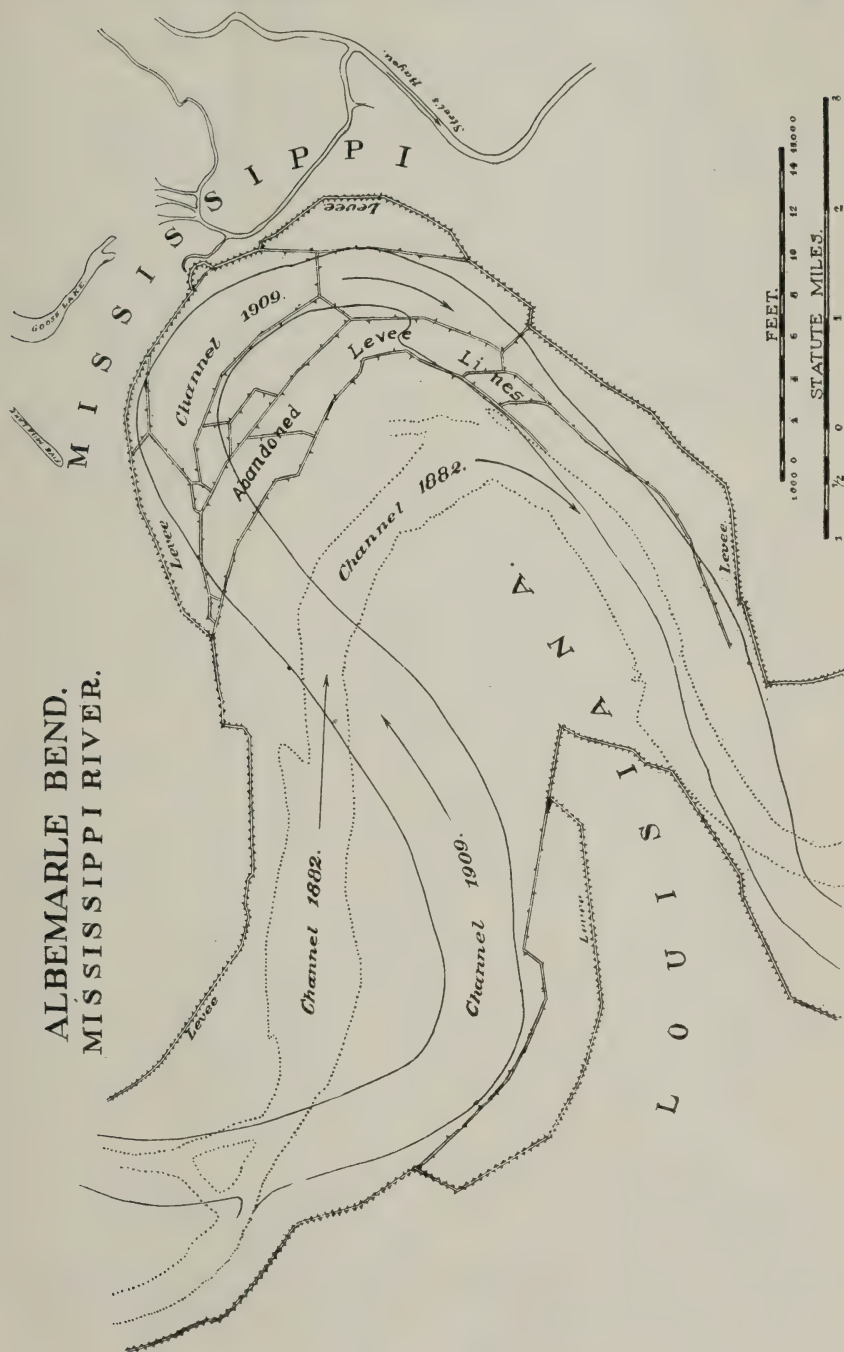
This map of Albemarle Bend is a picture of what will take place in bend after bend in the Mississippi River if that lawless stream is allowed to have its way. It would be extravagant, perhaps, to



say in all of them, and yet hardly so if we give the river time enough. The maintenance of the levee system under the burden of such frequent and never ending renewals of the present costly embankments would be hardly possible. Even if the cost could be borne, such a system could not command the confidence necessary to high and enduring prosperity. The community would be like an army encamped upon a plain in a hostile country without means of defense and liable to attack at any moment. The people would be subject to incessant alarms. The exigency presented at Albe-marle Bend has its parallel at several other places on the river now, and they will develop year by year elsewhere until all the actively caving bends shall have been securely protected.

THE GREENVILLE BENDS

We have here in one map the most interesting reach of the river, and one containing two of its most important revetments, besides a third of less importance, and the locality presenting just now the most emergent necessity for another. Speaking of bends, here they are—one of the finest examples of nature's engineering which the world has to show; so majestic in their sweep, so symmetrical in their curves. Guided by no compelling feature of mountain or rock, they look as though they had been laid out with intelligent purpose to establish the equilibrium of forces on which the stability of the channel depends. This long sentence requires an explanation. The flowing water in the channel has a certain erosive force, depending on its velocity. The bank has a certain resisting strength, depending on the material of which it is composed. When the erosive force is relatively greater the bank caves. A caving bend tends to return upon itself, and by and by it cuts off its own neck. This shortens the river by the difference between the distance across the neck and that around the bend. This produces an increase of velocity for a distance above and below the cut-off. This increases the caving action. This extends the bends, and so lengthens the river and reduces its velocity and diminishes caving. And so, through ages and ages past, the Mississippi has vainly tried to find some equilibrium between the velocity of its current and the strength of its banks which would give it stability. It finds this condition in increasing degree as it nears its journey's end, as a man finds peace in his old age. In the lower reaches of the river its slope flattens out and its velocity diminishes, while the banks are formed of finer sediments than those deposited in the upper reaches.



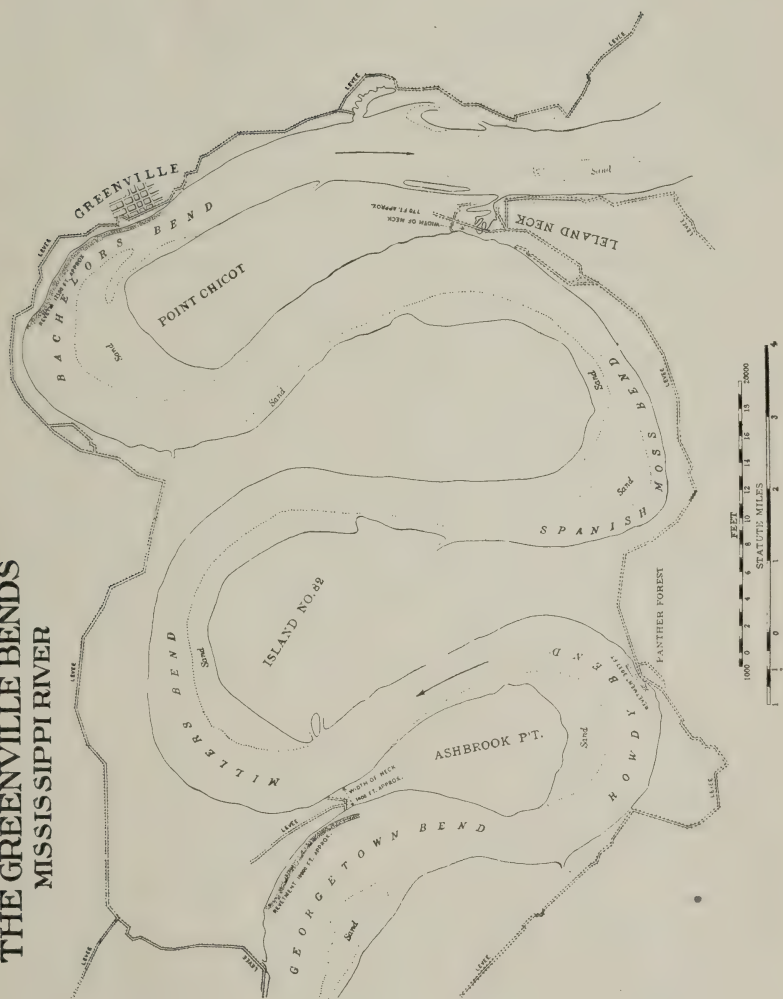
and have greater strength to resist erosion. As a consequence, caving is less active and the river is straighter.

The Greenville Bends lie in the region of active bend making and neck cutting, as the numerous crescent-shaped lakes in that part of the valley testify. Those are all abandoned bends left inland by cut-offs. The Greenville Bends are very old. Since a time when the memory of man runneth not to the contrary they have, until recently, maintained through their graceful curves their even flow and a good channel. But the inevitable cycle of change has overtaken them. As long ago as 1888-9 the neck connecting Ashbrook Point with the Mississippi shore had reached a dangerous stage of attenuation. With four such great bends following one another in immediate succession, each with a narrow neck, a cut-off at the upper one could hardly fail to be followed by like disasters at the others. They would all let go in quick succession. Such a disturbance of the river's regimen as would be produced was never known. The suddenly liberated stream would run riot and play havoc with its banks and everything on them in all that country. To guard against such a disaster a revetment was begun at Ashbrook Neck in 1890, and has been maintained in effective condition, and extended from time to time until it now holds nearly 2 miles of bank front. It is in good condition with every promise of permanence. There is no doubt that it has been worth many times its cost.

After many years of stability the bank in front of Greenville began to cave actively in 1882. By 1894 the total recession amounted to 4,000 feet. While this was going on, in 1887, a spur dike revetment was placed in front of the city. This is a form of bank protection consisting of projecting spurs or dikes at intervals along the bank. The river promptly flanked the dikes and went on with its work, leaving the dikes standing out the channel. In 1891 the standard brush and stone revetment was substituted, and has been maintained since with upstream extensions, as needed, and is at present about 12,500 feet long, and in good condition with promise of permanence. It has undoubtedly saved the city of Greenville from destruction and the levees in that vicinity from an experience like that shown on the map of Albemarle Bend.

At Panther Forest, in Rowdy Bend, is a new revetment put in a year ago to protect the levee at that place. The point of greatest interest now, however, in the Greenville Bends is Leland Neck. This neck has been shrinking slowly for several years, but only within the last year set up the somewhat unusual and dangerous

THE GREENVILLE BENDS MISSISSIPPI RIVER



action of cutting upward from the lower side. The map shows the irregular pockets which have formed. These are not very deep, but in the case of a heavy overflow across the neck would be dangerous. Levees have been built, as shown on the map, to guard against that overflow. But the situation requires a revetment and the urgency for it is very great.

A revetment was begun in 1887, at Cowpen Neck, immediately above the city of Natchez, to prevent a cut-off at that place. It has been extended progressively as necessity demanded until it now covers 21,848 lineal feet of bank in two detached sections, with an unprotected gap between them of 1,400 feet, which requires revetment to make the work complete. That the cut-off would have taken place but for this work is certain, and that the damages would have been many times the cost of it is equally certain.

At Walnut Bend, Ark., 281 miles below Cairo, a caving bend has been working its way for a good many years toward the St. Francis River, threatening, if unchecked, to cut off a considerable section of the lower end of that stream. It is necessary to leave open the foot of each of the large basins like the St. Francis (which contains about 6,000 square miles) for the escape of surface water into the Mississippi. A cut-off by the Mississippi River into the St. Francis at Walnut Bend would give that river a new mouth, expose all that part of the basin lying below to inundation and flood the basin with backwater for many miles upstream. A revetment has been begun and is in progress there to guard against that disaster.

IMPROVEMENT OF THE CHANNEL FOR NAVIGATION

The only obstacles to navigation in the Lower Mississippi are the sand bars. There is an occasional snag, but they have ceased to be the terror they once were; they make no serious trouble any more. The natural depths over the bars often go down to 4 or 5 feet during the low water season. By the work done under the Mississippi River Commission this was first increased to 8 feet, and then to 9 by annual dredging, which latter is the depth now named in the law. This is accomplished by a fleet of nine hydraulic dredges at an expense of about \$250,000 per annum, or something over, exclusive of the original cost of the dredges.

It is assumed here that the popular movement in the United States for the development of internal waterways has serious meaning, and that it will take practical shape in the not distant future. When it does, the line from the Great Lakes to the Gulf will be the

chief of them all. That part of it lying below the mouth of the Ohio will certainly follow the channel of the Mississippi. In view of this probability—certainty, almost—the subject of revetment has an interest and importance independently of its relation to the preservation of the levees. The talk is of a 14-foot channel. Some suggest more, but no one less. To maintain a channel 14 feet deep down the main stem of the Mississippi will be possible, and by means similar in a general way to those by which the 9-foot channel has been obtained, but they must be far more thorough-going and effective. The present channel is 250 feet wide; the 14-foot channel will have to be 500 feet wide. To make the present channel the cut across a 5-foot bar need be only 4 feet deep; to make the deeper one it must be 9 feet deep. The cross section of one cut is a thousand square feet; the cross section of the other will be 4,500 square feet. At low water the bars act as dams between pools above and below them. Such large cuts through those dams will tend to lower the upper pools. This in the aggregate will tend to lower the whole low water surface of the river. This will bring up bars heretofore submerged too deeply to obstruct navigation, which will also require dredging. The whole low water discharge of the river will go downstream more rapidly than now. This will tend to drain the pools. That will require deeper cutting to maintain the navigable depth. This shows how foolish people are who talk about a ship channel to St. Louis unless they propose to dig it and hold the water in it by locks.

To maintain a 14-foot channel by dredging, it will be necessary to begin the work long before the water falls to that depth—say, when it falls to 24 feet or earlier. It will also be necessary to transport the dredged material a much greater distance than at present. One of the difficulties of the work as carried on now is the tendency of the sand to run back into the cut. The deeper cut will increase that tendency. It will be necessary to deposit the sand farther away from the edge of the cut. This, with the increased quantity to be moved, will greatly augment that part of the work. The cuts will also have to be much longer, because the bars, as a rule, have flat slopes. Undoubtedly there will be difficulties attending the greater width and depth of the cuts that can not be foreseen. Such an one suggests itself in connection with the broader bottom of the cuts. With a width so great as 500 feet the river may take a notion to amuse itself, as it does in crossing its natural bars—by wandering about and making subsidiary channels here and there. No one can

tell just what it will do in that situation. It will also be more difficult to make good any accident, or slip, or delay which may occur. We are bound to anticipate that the 14-foot channel will carry a great commerce. It will not do to have it full of dredge boats.

The difficulty of the problem is in the quantity of sand to be taken care of. It is easy to handle a little of it, but there is a point at which the undertaking would become impossible. To a traveler on the Mississippi at low water the most interesting feature of the landscape is the sand bars piled up along the channel, 10, 20, 30 feet high, miles in length and thousands of acres in area. Where does the material in them come from, and how does it get there? It comes from the caving bends above, from which it is transported only a short distance, to be deposited as soon as and wherever the current falls off in its velocity. The Mississippi River is a great freight carrier. It classifies its freight to a nicety. It carries some fine sediments from the Missouri River to the Gulf of Mexico. Some coarse stuff it rolls along the bottom out of the bend and up the next bar, to leave it there. Intermediate between these it lifts, floats, pushes, or rolls the particles according to their specific gravity and the velocity of the current at the moment. But by far the greater part of the material which forms its bars is moved only a short distance. If the caving were stopped, the bars would speedily shrink to small proportions. This is the way to a 14-foot channel—revetment of the banks to reduce bar building to a minimum, and dredging for the balance.

A little the most economical way to cover all the caving banks would be to begin at the head and work continuously downstream. But that is not greatly important. Revetments can be put in here and there where most needed without great sacrifice. Practically the work can be done in no other way. It will take many years to reach a 14-foot channel, even if we begin now with that specific depth in view. It will necessarily come progressively, foot by foot, partly by dredging, and, if we proceed wisely, partly by revetment. Both forms of work will be the mere continuance of work now going on, only on a larger scale—more plant, more men, more money. We will not, at least we need not, for some years to come, build any revetments for the sole purpose of deepening the channel. Each one will serve a double purpose—to protect a levee line; to prevent a cut-off; to improve a harbor; to save a city, or the like, and, at the same time, contribute to the diminution of bar building and the final fixation of the bank with that complete control of the river

which the people of the United States will secure sometime whether we in our generation help or hinder.

As has been stated, the popular demand so far has been for 14 feet from the Great Lakes to the Gulf. The adverse report on that scheme by the Board of Engineers appointed by Congress to consider it, which has been made public, may or may not influence the attitude of the advocates of the project. But it must be reckoned with. And in view of it the friends of waterway improvements may well consider whether it is necessary to lay so much stress on 14 feet, or any particular depth. The vital end to be reached is to develop waterways as a supplement, or addition to the railroads of the country in handling its transportation; as many of them as will be useful and as capacious as will be profitable. The argument rests on the economy—the absolute, unchangeable, everlasting economy of water transportation; its immediate economy in freight costs, and its large and far-reaching economy in consumption of coal, wood and iron, and the conservation of natural resources. As compared with these considerations the apparent demand, or want of a demand, to-day on the part of shippers for waterway facilities ought not to be controlling.

It is a disappointment to us all that commerce has not taken advantage of the increased channel depths in the Mississippi from St. Louis to New Orleans as they have been developed within ten years past. But the reasons are not far to seek. The first is the uncertainty of their permanent maintenance. They depend upon annual appropriations by Congress. Those are liable to fail. They have failed occasionally in the history of the work. It would take millions of dollars to equip the Mississippi River for the commerce it is now ready to carry. Capital hesitates. This hesitation is not unnatural in view of the history of the work. Thirty years ago the Mississippi River Commission started out with large promises of an improved channel. We were to have 8 feet from Cairo down in short order. We did not get it. We had the art of revetment to learn. Miles of our work failed. Years and years were spent in experiments—not supposed to be experiments at the time, but experiments as results proved. Such experiments are very tedious and long-drawn. It takes a whole season to put a revetment in a bend. If it holds through the next flood, good. If through the next, better; if the next, still better. But the proof is not yet. It may do all that and then fail. When it goes out, what was the reason; did the river get under it at the inner edge and dig out a cave

behind it into which it slid? Sometimes. Did the water from some inland lake or swamp seep through the sand layers behind it and wash out a cave under it, or soften the soil so that the whole bank, revetment and all, sloughed into the river? Sometimes. Was the structure of the mat too stiff and unyielding so that it would not fit itself to the curvature of the bank? Sometimes. Was it too limber, so that the current doubled it up? Sometimes. Was there a lack of sufficient stone to hold it down? Sometimes. Often and often these questions were asked, and years were spent in answering them. Numerous revetments were built and rebuilt over and over. Congress became so disgusted that at one time it forbade the further use of revetments. But it repented of that folly two years later.

At last the problem seemed to have found a solution. The fascine mat now used very rarely fails. It has stood all the tests for fifteen years. But with its stone riprap it costs \$30, or a little more, per lineal bank foot. Our original estimate was \$12. And it swallows up willow brush at a fearful rate. At the darkest day of these discouraging experiences invention gave us the hydraulic dredge capable of moving sand at the rate of thousands of cubic yards per hour. It has given us the 9-foot channel. It is not strange that commerce became discouraged. The steamboats and dredges in use wore out. Their owners hoped to build larger ones to utilize the improved channel and waited. When they got tired of waiting they turned to other enterprises.

Another reason why commerce on the river lags is that people are afraid of the railroads. It is a curious circumstance that under the law as now administered, a railway may lawfully cut rates to any extent to meet the competition of water transportation, as though that mode of conveyance were a thing to be outlawed and destroyed, if possible. It may not give a special rate to a shipper unless he is in situation to ship his goods by water; then it may. It is worth considering whether that favoritism ought not to be stopped.

Another reason why commerce delays to improve its opportunity on the Mississippi River is that for ten years past there have been so many inviting fields of business elsewhere. It is the same thing that makes it hard to man our merchant marine with American sailors. There are too many better jobs on land. River navigation waits on the initiative of individual men. Each man accommodates himself to existing conditions. If the railroads overcharge

him he grumbles, but pays the rate. If his business suffers from delay in transportation, he puts up with it. It will take some strong, courageous, optimistic man, or group of men, to make a start in the navigation of the Mississippi below Cairo. Once started on a foundation of confidence it will grow. If there were a channel 10 feet deep from Chicago to New Orleans to-day with public confidence in its permanence, it would be crowded with boats within ten years. If we postpone work for a "demand" and discover no demand until we see men standing on the bank with money in their hands, there will never be any improved waterways. God Almighty did not wait for a demand from commerce before He made the Great Lakes.

Everybody is afraid of the Mississippi River. The people who live in its alluvial valley are afraid of its floods; steamboat men are afraid of its bars. The inhabitants are just beginning to take courage. The water has been held at bay for ten years. But an extraordinary flood, a few bad crevasses and the inundation of 4,000 or 5,000 square miles would plunge them into a despair again from which it would take a long time to recover. We have had a 9-foot low water channel below Cairo nearly all the time for a little less than ten years. But it has not been entirely trustworthy. There have been some slips in the management of the dredges and some bars have gotten ahead of us for a few days a few times. Not often, nor for long, but enough to keep alive the sense of uncertainty. So men who would build big boats to navigate it wait, and keep waiting.

There is a wiser way which our fellow-citizens of Kansas City are taking. They have organized a million-dollar corporation there to construct and operate on the Missouri River a line of freight boats adapted to navigate its shallow channel just as it is. They are to have low decks, light draft, ample motive power and every feature of construction to accommodate them to the conditions which exist in the Missouri, just as the Germans have done on the Rhine. They have enlisted the services of experts to design a steel boat for the purpose and they expect to make it go and make it pay, and they will. That is the way to get there—turn your face in the right direction and start.

We shall have, or ought to have, in this country some day an infinite ramification of navigable waterways, from the little ones, with their shallow motor boats, to the lordly Mississippi, with its broad, stable, improved channel somewhere from 14 to 20 feet deep.

We will not run ocean vessels or lake vessels in our rivers and canals, but boats suitable to them. We shall develop the art of freight handling and terminal facilities to the point that will reduce the cost of transfer from boat to boat, or boat to land, to an unimportant amount. With our waterways, our railways, and our trolley ways combined, we shall beat the world in transportation, as we have in everything else. Between the present and that consummation, however, are years of study, experiment, discussion and preparation. Only at one place are we ready to proceed now with work that will have its useful part in the final scheme, whatever form that may take, and that is on the banks of the Lower Mississippi. It would be worth while to do it if there were no alluvial valley to protect—just to build up confidence and lead the way to the large improvements to come. But when we take into account the levees, the lives and property and prosperity which depend on them, the money which has been invested in them, the disasters which would attend their destruction, and the indispensableness to their preservation of the same revetments which will contribute to the improved channel we have a case of emergency the statement of which more words would weaken rather than strengthen.

What is needed—and that is the point to which this brief is directed—is no great sum of money at once, but something like two million dollars a year in addition to the usual past appropriations for the Lower Mississippi in some form of regular and unfailing provision for five or ten years to come.

Errata

A letter from Capt. J. A. Woodruff, Corps of Engineers, received after his article, A Combined Position Sketch (see page 50), had been printed, requests that the following corrections be made: Page 53, 7th line, for *east* read *west*; 8th line, for *west* read *east* in both cases; 16th line, for *eastern* read *western*; 17th line, for *west* read *east*; page 54, 1st line, for *western* read *eastern*; 2d line, for *east* read *west*.

THE WRIGHT FLYER AND ITS POSSIBLE USES IN WAR

BY

LIEUT. F. E. HUMPHREYS

Corps of Engineers

Flying consists in sustaining a body in the air against the force of gravity by means of the dynamic action of the air against some movement of the body. Men have attempted to fly in three different types of machine, the ornithopter, which flaps its wings in imitation of the flight of birds; the helicopter, which lifts itself by the use of vertical propellers, and the so-called aeroplane, which is sustained by the reaction of the air on inclined surfaces.

Neither the ornithopter nor the helicopter has given practical results. The aeroplane is the one which has made all the flights worth mentioning and is at all practical.

The word "aeroplane" is decidedly a wrong name to apply to the present day machine, as the surfaces used are not planes but curved surfaces. The Wright brothers and several New York papers have introduced the use of the word "flyer," which is much more appropriate.

The Wright flyer which has been purchased by the Army for instruction and experimentation consists of two main surfaces, a forward elevating plane, a steadying plane in rear and two vertical rudders for steering.

The main surfaces do the actual supporting of the flyer. They are about 36 feet long, 5.2 feet deep, superposed with 5.2 feet between the surfaces. These, like the main surfaces in other successful machines, are concaved downward, as can be seen in the illustrations.

The forward plane is used for elevating and depressing the flyer. It is about 15 feet long and 3 feet wide, arranged so that it is concaved on whichever surface is bearing. This is seen in Figs. 1 and 2, in one of which it is in position for elevating and the other for depressing.

The steadying plane is of the same form as the front elevating plane, but is rigidly attached and has no motion. This plane was at first used superimposed on the front plane and having the same motion, but was changed to the rear to give greater steadiness. Fig. 3 shows the old arrangement, and Fig. 4 the new.

The vertical rudders are two planes, each about $1\frac{1}{2}$ by 6 feet, placed $1\frac{1}{2}$ feet apart and 8 feet behind the main surfaces. They

guide the flyer in the air in the same manner that a rudder guides a ship in the water.

To secure lateral stability the tips of the main surfaces can be warped. This idea was first used by the Wrights and is one of their patents, but it is now used by several foreign aviators, notably Bleriot and the Antoinette Company. The lawsuit of the Wrights against the Sydney Bowman Automobile Company when they imported a Bleriot machine to sell in this country was over this point.

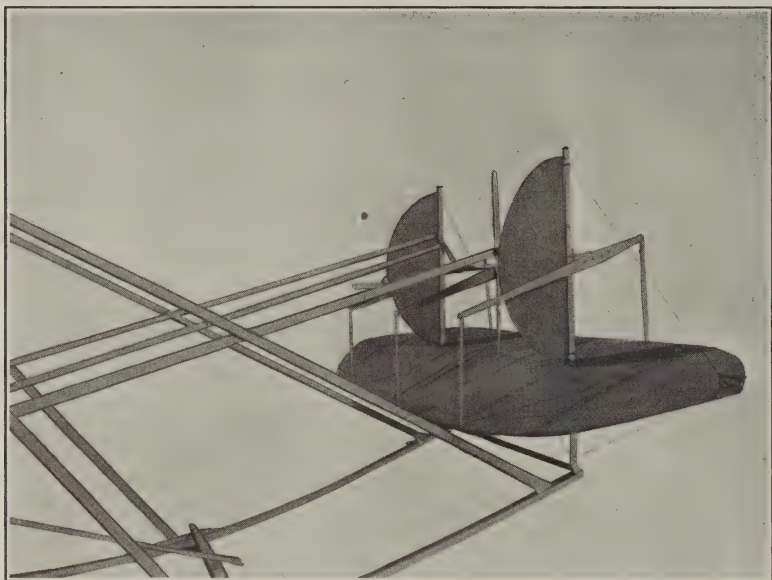


Fig. 1. Forward plane in position for elevating.

The main surfaces are in three parts, a main central section and two wing tips. The central section is 13 feet long and each tip $11\frac{1}{2}$ feet long. There are between these sections joints movable in a vertical direction. The entire front of the main surfaces is trussed by wooden struts and steel wires and is immovable. The middle section is similarly trussed in rear and also cross-trussed from front to rear. The end sections, however, are trussed in rear, as shown in the diagram (Fig. 5).

From this it is seen that if the lower wire is pulled toward the left the right tip will be pulled down and the left up, and vice versa. Then, as the front of the surfaces is immovable, a movement of the wire in any direction will warp the tips and cause them to present a greater angle on one side and a lesser on the other side.

thus giving an increased lift on the side of the greater angle and a diminished lift on the other side. (See Figs. 6 and 7.)

(For small angles the greater the angle the greater the lift. The exact law of this lift, like all other aero-dynamic data, is in dispute, as all the data comes from men who have not built successful machines, and the men who have built successful machines either say nothing or imply that the existing law tables are not correct.)

The flyer is given motion by two propellers about 9 feet in diameter and 11-foot pitch, which revolve in opposite directions at about

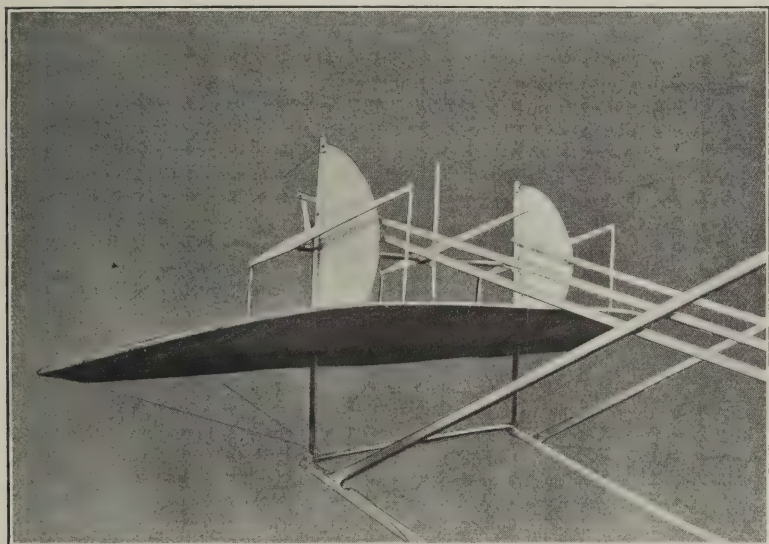


Fig. 2. Forward plane in position for depressing.

350 revolutions per minute. They are driven by chains from the engine.

The engine is gasoline, four cylinder, water cooled, running at about 1,200 revolutions per minute and giving about 36 horsepower at that speed. It weighs 165 pounds, exclusive of radiator and magneto.

The flyer altogether when leaving the rail with water, gasoline and two men weighs about 1,100 pounds; it goes at a rate of about 40 miles per hour and carries enough fuel for a flight of three and a half hours.

There are several questions which are almost invariably asked by people looking over the machine. One of them is: "What happens when your motor stops? Do you have to come down?"

A flyer is only sustained in the air by the reaction due to its speed, and whenever this is lost the flyer will drop. However, this is never totally lost, as the same force that causes the descent can be used as a motive power to keep up the speed. In other words,



Fig. 3. Mr. Orville Wright flying. Figure shows the old arrangement of forward planes.

if the motor stops, the machine is pointed down at an angle until the component of gravity in the direction it is going is equal to the push required. This keeps up the speed necessary for control, but, of course, makes the flyer gradually descend.

The present flyer can glide down without motor at an angle of from 1 in 5 to 1 in 7.

The next question is: "What use are these things going to be?"

From a military standpoint, the first and probably the greatest use will be found in reconnaissance. A flyer carrying two men can rise in the air out of range of the enemy, and, passing over his head out of effective range, can make a complete reconnaissance and return, bringing more valuable information than could possibly be secured by a reconnaissance in force. This method would

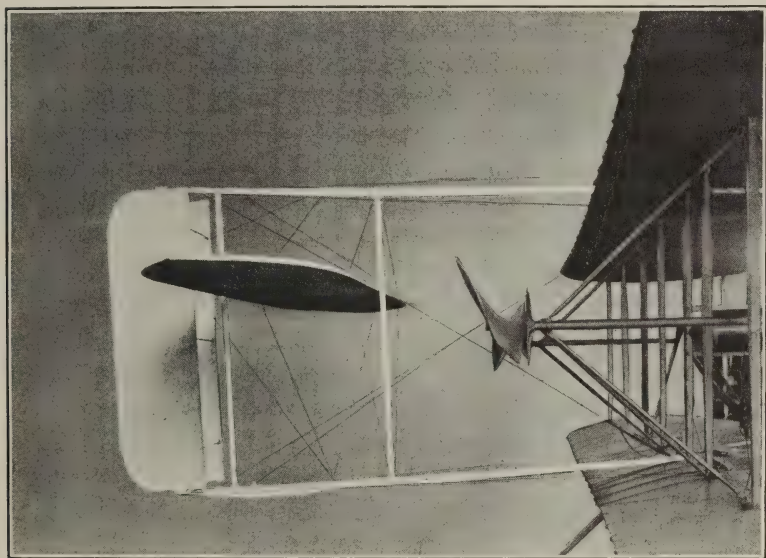


Fig. 4. Steadying plane, showing new rigid arrangement at the rear of the flyer.

endanger the lives of but two men; the other would detach several thousand men for a length of time and endanger the lives of all.

The next use will probably be in carrying messages. A flyer will average a speed of 40 miles an hour in a straight line. Excepting the telephone and the telegraph, there is no other method of communication as rapid as flying. Automobiles, motor cycles, etc., usually do not average this speed, and very often have to go around two or three sides of a square to get to where they are going. This would be particularly valuable for carrying messages between bodies which have been more or less separated, as between the main attack and a flank attack, and between the main body and independent cavalry, or cavalry on a raid.

Another time where advantage might be taken of the speed of these machines is when officers of high rank might desire to give personal supervision at a distant point of the line or to go from one point to another for a council of war. This is particularly the case in modern armies of large size where the front is 70 or 80 miles long. Take an army on a 70-mile front, the army consisting of three parts, the center and the flanks. The commanding officer desires a council of war. The two flank commanders are then about 20 to 25 miles from main headquarters. These men could be brought to the council in three-fourths of an hour by a flyer and returned in about the same time. If they tried to come in an automobile, or on horseback, they might find no good roads, and what there were would probably not be straight and would be certain to be congested. Their progress then would almost certainly be slow, and they would probably be kept from their commands for hours.

As the United States was the only first-class power which signed

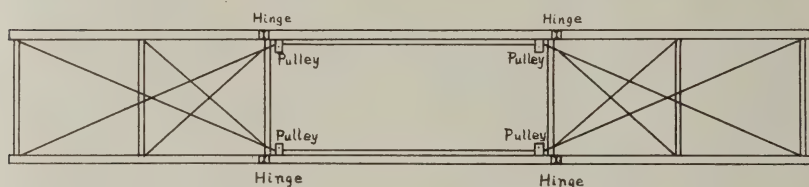


Fig. 5. Truss wires arranged for warping the rear frames of the wings.

the Hague agreement as to dropping projectiles from balloons, it is not probable that this agreement will be in force in future wars. Probably a large amount of damage could be done to the personnel of the enemy when in mass, or in a raid to the storehouses and depot, by projectiles dropped from a flyer. That any could be done to fortifications or ships is doubtful.

Flyers might also be used to give warning to war vessels and fleets of an impending attack by submarines. A person looking at water can see down into it only when the angle of the line of sight with the vertical is less than about 50 degrees. In other words, a man at a masthead 100 feet high could not see a submarine until it was about 125 feet away; a man in a flyer 3,000 feet directly over a ship could see a submarine approaching within a radius of 4,000 feet of the vessel and by circling around could greatly extend the zone of protection.

Another remark frequently made is: "Well, I don't see what use these things are if you can't fly except in a large open plain and in a calm or almost a calm."

This is quite reasonable, judging from the flights at Fort Myer and College Park. However, conditions at both places were quite different from those of actual warfare.

At Fort Myer, Orville Wright had a new machine 4 feet less in width and 9 inches less in breadth than usual. He, naturally, did not want to try this machine in anything except a calm, and he waited until the weather conditions were favorable for trying it. When used to the machine, he went up in winds up to 15 miles per hour, but never more than this. His object was to go through the

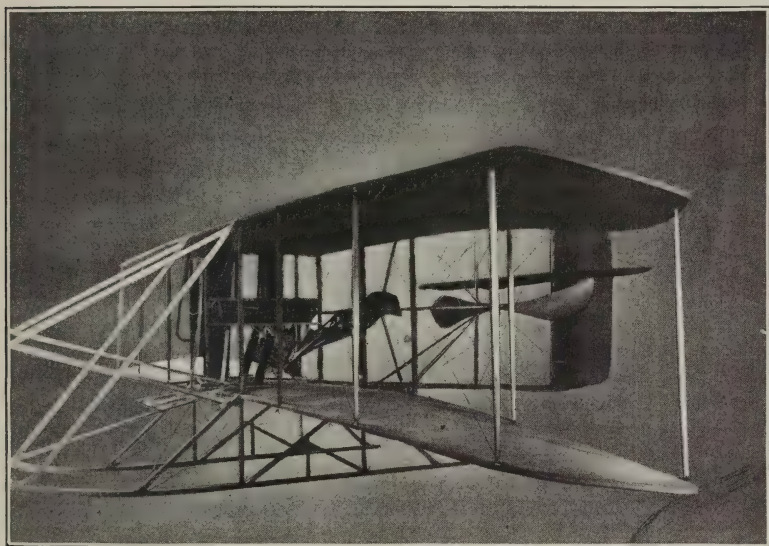


Fig. 6. Wing tip warped to increase its lifting effort. The far tip is simultaneously warped in the opposite direction.

tests and sell his machine to the Government, and he did not care to run any risk of smashing the machine beforehand.

At College Park the object of Wilbur Wright was to instruct two officers in handling the machine. These men had to receive their instruction in a calm and gradually advance to higher wind. To have taken the machine out in high winds would not have been any instruction to the officers and would have risked smashing the machine and having it out of commission during weather favorable for instruction.

In the hands of experts these machines ought to be able to work in winds up to 35 miles per hour and would be able to work in fields much smaller than College Park.

Of course, accidents of one kind or another are bound to occur, and in open country the damage resulting from any cause, such as the engine stopping or a wire breaking, is greatly decreased. In flying over rough country any accident is liable to cause serious consequences, especially if the flyer is low down, as it may not be able to avoid trees, houses, trolley wires, telegraph poles, etc. At a great height this risk lessens, as there is then a much larger radius from which to select a landing place.

Of course, in time of war flyers would cross any kind of country,

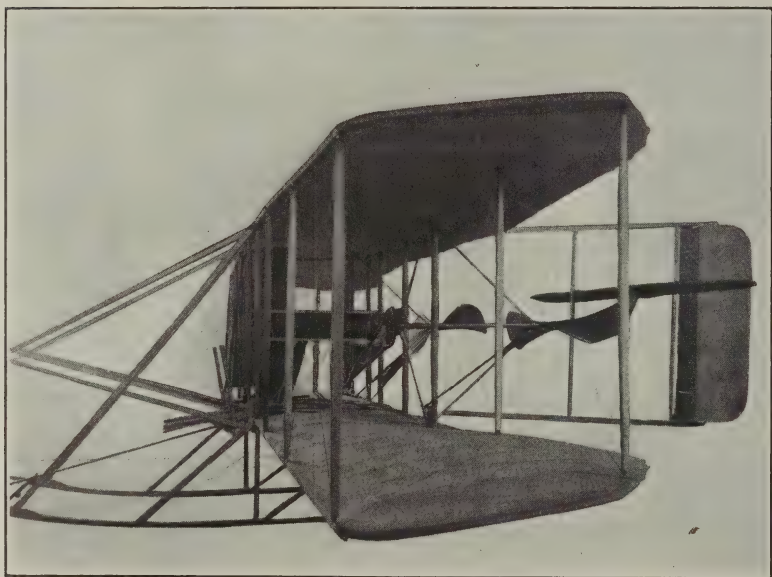


Fig. 7. Wing tip warped to diminish its lifting effort. The far tip is simultaneously warped in the opposite direction.

but in their present state of development there is no more reason for risking the lives of aviators by sending them over rough ground unnecessarily than for risking those of soldiers by firing real projectiles at maneuvers.

In addition, it must be remembered that if because of a storm the flyers can not be used the Army is no worse off than if it had none, and the cost and number of men used is insignificant. One officer, ten men and two wagons are a full equipment for a flyer.

Figures 3 and 8 are from photographs borrowed from the office of the Chief Signal Officer, U. S. Army. The remaining photographs are by Sergeant-Major Lefever, Engineer School Detachment.

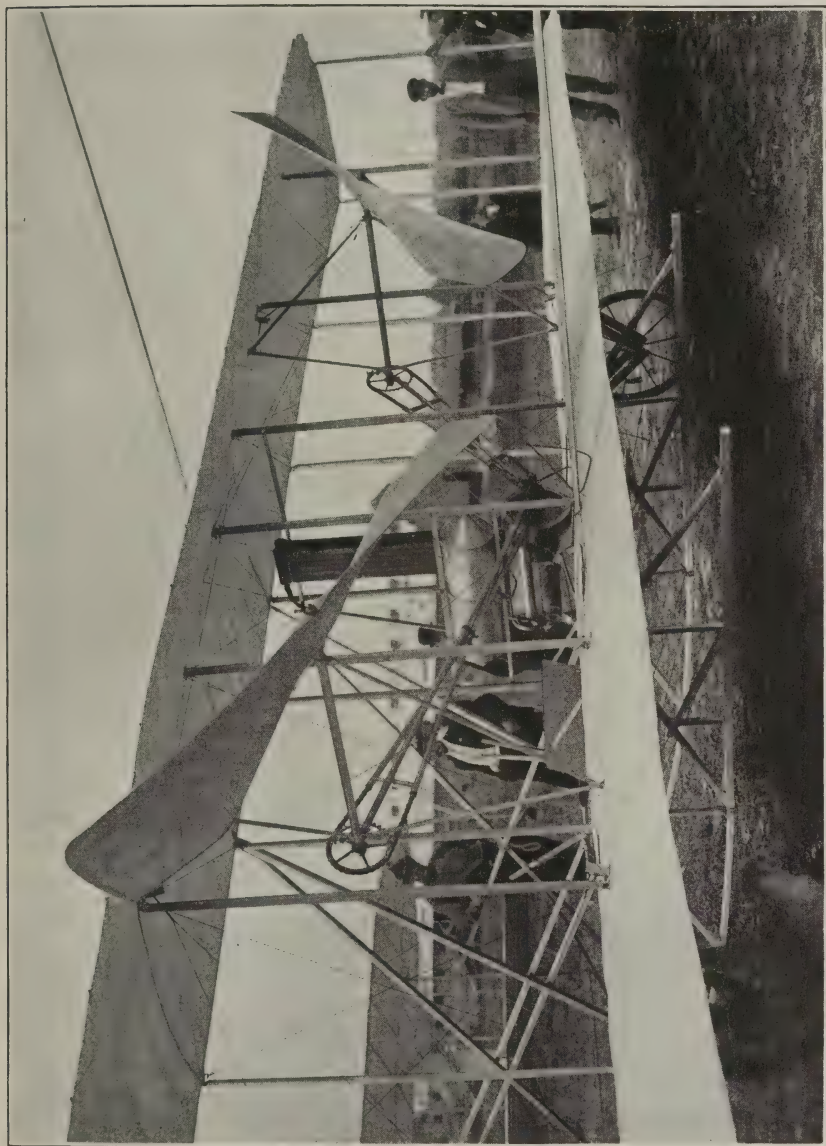


Fig. 8 Showing the arrangement of motor and propellers.

EXPERIMENTAL FIRING AT CASTLE WILLIAMS

Copy of Letter to the Secretary of War

NEW YORK April 15—1812.

SIR:

Having frequently heard you express a desire to have the resisting Power of Castle Williams tested by actual Experiment, I made an arrangement with Commodore Rogers for the purpose, and the following article from this mornings Gazette will show the Result: I prefer this mode of communication, because having no knowledge or no participation with the Author of the article, it cannot be suspected of partiality.

“As they (the frigates President & Essex) passed they fired seven shot at Castle Williams for the purpose of trying its strength, Five Balls hit the Castle, & two struck the Rocks forming the foundation of the Fabric. On an examination of the effect of the Balls we are happy to find that much less injury was done than was anticipated. *Three* 24 pound Balls entered one of the Embrazures of the lower Tier, knocked off a small part of the ornamental edges. One of the Balls hit one of the mounted Cannon of the Castle in which it made a small indentation *carried away* the Cap Square and Trunion plate and the fore part of the Carriage—one Ball struck the Embrazure of the second Tier directly over the one above mentioned and one was a point blank Shot on the solid part of the Castle which penetrated only 3 Inches & did no Injury to the Wall. The Walls of Castle Williams are nine feet thick and we may conclude from this experiment upon them while yet in a green state that no apprehension need be formed of their being Battered down.” Thus far the Gazette; but as I was within the Castle, and at the Gun next but one to the Gun stricken I know that but one Shot entered the embrazure, the other two being buried behind the flat Stones that form the sides & top. 2d That the Cap Square was not carried away & only bent, with the end bruised, the part of the Carriage that was carried away was inconsiderable, and the Gun was capable of continuing the action; it is remarkable that the blow did not occasion any recoil. 3d the Ball that struck the Wall penetrated just 1-3 of its diameter & fell dead at the Bottom of the Wall, the one that struck the Gun & Cap Square was broken into 3 or 4 pieces. I carried this Ball & some of the pieces afterwards on board the President at the Quarantine Ground & left them with Commodore Rogers. The distance at which the attack was made was about 400 yards—less than point blank distance.

Lieut. Partridge goes to Pittsburg tomorrow to meet Brig. Genl. Hull & take his orders.

I have the honor to be
with the greatest Respect
Sir Your obed Servant

JON. WILLIAMS

SELECTED ARTICLES OF ENGINEERING INTEREST

Compiled by Henry E. Haferkorn, Librarian, Engineer School

BRIDGES.

The bridges of New York City: Brooklyn Bridge, and other Brooklyn bridges. By T. K. Thomson. Engineering Magazine, October, 1909, pages 49-69. Illustrated.

Masonry arch bridges of the world with over 175-foot span. Engineering News, September 2, 1909, pages 255 and 256.

Modjeski's report on design and construction of the Manhattan Bridge over the East River at New York City. Engineering News, October 14, 1909, pages 401-409. Illustrations, diagrams, tables.

Notes on the replacing of the superstructure of the Harlem Ship Canal Bridge. By Horace J. Howe. Proceedings American Society of Civil Engineers, November, 1909, pages 1261-1281.

Two curious bridges on the Indo-China railways. Engineering News, October 7, 1909, page 382. Diagrams.

CONCRETE, PLAIN AND REINFORCED.

Impurities in sand for concrete. (Discussion.) By Sanford E. Thompson, etc. Proceedings American Society of Civil Engineers, September, 1909, pages 973-989. With tables.

Tests of plain and reinforced concrete columns. By M. O. Withey. Engineering News, September 16, 1909, pages 300-303. Illustrations, diagrams, tables.

Progress-report of special committee on concrete and reinforced concrete. (Discussion.) By John Stephen Sewell, etc. Proceedings American Society of Civil Engineers, September, 1909, pages 930-952.

CONSERVATION OF NATURAL RESOURCES.

President Taft on conservation and the work of the Reclamation Service. Address at Spokane, September 28, 1909. Engineering News, October 7, 1909, pages 380-382.

DAMS.

The failure of the Fergus Falls, Minn., city dam. By Franklin McMillan. Engineering News, October 14, 1909, pages 393-395. Illustrated.

Heightening the Assuan Dam across the Nile. By Fred. Hall Fowler. Engineering News, September 30, 1909, pages 339-344. Illustrations, diagrams.

Some observations on the stability of dams. By J. F. Jackson. Journal Western Society of Engineers, October, 1909, pages 619-640. Diagrams.

ENGINEERS.

Breckinridge, Cabell, M. Am. Soc. C. E., 1846-1907.

Memoir prepared by Onward Bates, President Am. Soc. C. E. Proceedings September, 1909, pages 1011-1014.

Brinckerhoff, Henry W., M. Am. Soc. C. E., 1845-1909.

Memoir prepared by Chas. H. Myers, M. Am. Soc. C. E. Proceedings Am. Soc. C. E., November, 1909, pages 1292-1294.

Leach, Smith S., Colonel, Corps of Engineers, U. S. A., 1853-1909.

Memoir, with portrait, and facsimile of signature. Engineering News, October 28, 1909, page 466.

Richardson, Henry Brown, M. Am. Soc. C. E., 1837-1909.

Memoir prepared by B. M. Harrod, Past President Am. Soc. C. E. Proceedings Am. Soc. C. E., October, 1909, pages 1180-1182.

Seymour, Horatio, jr., M. Am. Soc. C. E., 1844-1907.

Memoir prepared by John Bogart, M. Am. Soc. C. E., and Alf. Noble, Past President Am. Soc. C. E. Proceedings Am. Soc. C. E., November, 1909, pages 1295, 1296.

FIRE-PROOF CONSTRUCTION.

Fire-resistant construction of buildings. (Discussion.) By Herbert M. Wilson, etc. Proceedings American Society of Civil Engineers, September, 1909, pages 953-972. Tables.

GAS AND OIL ENGINES.

Oil and gasoline engines for contractor's use. Engineering-Contracting, December 8, 1909, page 500.

HAULING.

The cost of hauling with traction engines and dump wagons as compared with hauling with horses. Engineering-Contracting, December 8, 1909, pages 501-505. Illustrations, diagrams.

HYDRO-ELECTRIC POWER PLANTS.

Hydro-electric power in Canada. By H. Holgate. (Discussion.) Proceedings American Society of Civil Engineers, September, 1909, pages 924-929, fold. plan, diagrams.

IRRIGATION.

Redemption of the great Valley of California. (Discussion.) By Wm. W. Harts, Corps of Engineers. Proceedings American Society of Civil Engineers, October, 1909, pages 1157-1162.

LOCKS AND LOCK GATES.

The accident to the Poe Lock gate at the St. Marys Falls Canal, Sault Ste. Marie. Engineering News, November 18, 1909, page 562. Illustrated.

The lock gates of the Panama Canal. Engineering News, September 16, 1909, pages 304, 305. Diagrams.

A reply to the criticism of the Burley type of lock. Engineering News, September 2, 1909, page 255.

PANAMA CANAL.

Extracts from the annual report of the Isthmian Canal Commission. Engineering News, November 25, 1909, pages 565-568. Illustrated.

Notes on the Panama Canal, past and present. By H. F. Hodges, lieut. col., Corps of Engineers. Engineering News, September 30, 1909, pages 348-352. Illustrations, diagrams.

The Panama Canal. By F. P. Stearns. Journal Association of Engineering Society, July, 1909, pages 12-26. Diagrams.

Plans for the spillway dam at Gatun, Panama Canal. Engineering News, September 23, 1909, page 336. Diagrams.

Records and cost of excavation on the main channel and lock work of the Panama Canal for the year ending June 30, 1909, with summaries of excavation costs. Engineering-Contracting, December 8, 1909, pages 487-489. With tables.

A sea-level canal at Panama: a study of its desirability and feasibility. (Discussion.) Bulletin American Institute of Mining Engineers, July, 1909, pages 623-666.

POLLUTION OF WATER.

Reports of Col. W. M. Black on the pollution of New York Harbor and the proposed Passaic Valley and Bronx Valley sewer outlets. Engineering News, October 21, 1909, pages 444-447.

PRESERVATION OF TIMBER.

A comparison of the various processes of preserving timber. By G. B. Shipley. Engineering News, October 14, 1909, pages 396-400. Illustrations, tables.

RAILROAD TUNNELS.

The New York tunnel extension of the Pennsylvania Railroad. By Chas. W. Raymond, brig. gen., U. S. A., retired. Proceedings American Society of Civil Engineers, September, 1909, pages 857-887. Fold. plans and diagrams.

The New York tunnel extension of the Pennsylvania Railroad: The East River Division. By Alf. Noble, chief engineer East River Division. Proceedings American Society of Civil Engineers, September, 1909, pages 888-900. Fold. plans and diagrams.

The New York tunnel extension of the Pennsylvania Railroad: The Cross-town tunnels. By James H. Brace, resident engineer East River Division, and Francis Mason, resident engineer East River Division. Proceedings American Society of Civil Engineers, October, 1909, pages 1016-1044. Illustrated, diagrams.

The New York tunnel extension of the Pennsylvania Railroad: The East River tunnels. By James H. Brace, resident engineer East River Division; Francis Mason, resident engineer East River Division, and S. H. Woodward. Proceedings American Society of Civil Engineers, October, 1909, pages 1045-1105.

The New York tunnel extension of the Pennsylvania Railroad: Contractor's plant for East River tunnels. By Henry Japp, resident engineer, S. Pearson

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& Son, Ltd., contractors for East River tunnels. *Proceedings American Society of Civil Engineers*, November, 1909, pages 1184-1260. Illustrations, fold. diagrams.

RECLAMATION OF LAND.

The reclamation of the arid lands of the West. *Scientific American*, December 11, 1909, pages 428, 429, 432.

ROADS.

Development of modern road surfaces. By W. H. Fulweiler. *Journal of Franklin Institute*, September, 1909, pages 155-183, and October, 1909, pages 260-300. Illustrations, diagrams.

Has experience demonstrated that the oiling of roads is the most satisfactory or economical method of preventing dust and preserving the road surface? (Discussion.) By S. Whinery and G. S. Davison. *Proceedings American Society of Civil Engineers*, September, 1909, pages 990-994.

Methods and costs of sprinkling road surfaces with oil. *Engineering-Contracting*, December 8, 1909, pages 492, 493. Illustrated.

Specifications of the New York State Highway Department for bituminous macadam and characteristics required of the bituminous materials. *Engineering-Contracting*, December 8, 1909, pages 490, 491.

WATER SUPPLY.

A combined water-supply, irrigation and power project. Plan, construction and purposes of the Los Angeles aqueduct. By Burt A. Heinly. *Engineering Magazine*, November, 1909, pages 161-174.

Water supply for the lock canal at Panama. By Julio F. Sorzano. *Proceedings American Society of Civil Engineers*, October, 1909, pages 1114-1143.

WATER SUPPLY OF TOWNS, ETC.

Methods and costs of laying about one and one-quarter miles of 20-inch cast iron water pipes in Cuba. *Engineering-Contracting*, December 8, 1909, page 494.

Some data on water-works maintenance and operation gleaned from a public service report. *Engineering-Contracting*, December 8, 1909, pages 494-496.

WATERWAYS.

The proposed Lakes-to-the-Gulf deep waterway. *Scientific American*, December 11, 1909, pages 433-436. Illustrated.

Present and prospective commerce of the Mississippi River from St. Louis to the Gulf of Mexico. *Engineering News*, November 4, 1909, pages 489-493.

WHARVES.

The reinforced concrete wharf of the U. S. Fruit Co., at Bocas del Toro, Panama. (Discussion.) By John Hawkesworth and J. B. Cameron. *Proceedings American Society of Civil Engineers*, November, 1909, pages 1290, 1291.

Editorial Notes

Our readers will find upon the cover of this number of the PROFESSIONAL MEMOIRS a name which leaves no doubt as to the branch of the Government service which is represented by this magazine. A word of explanation as to the retention of the first part of the name may possibly be desired by those who have expressed a preference for some other designation. A "memoir" is defined as an account of something important or deemed worthy of record, especially when addressed to a public body or a scientific association. It has long been used in this sense in the engineer service, a report being described as consisting of "a drawing and a memoir." Officers reporting for examination for promotion were required to submit "professional memoirs." It is common for a contributor to write us that he is forwarding a "memoir." The name is appropriate and distinctive. A year has been spent in advertising the magazine under this name throughout this country and abroad. To change the name now would cause a serious loss to the publication. It has therefore been retained in the expectation that it will succeed in becoming well known and respected.

[The following extract from a letter of Col. C. McD. Townsend, Corps of Engineers, is interesting in connection with the predictions of disaster from such accidents that have been advanced in opposition to the lock canal at Panama. The locks at the Sault have now furnished examples of collisions with both upper and lower gates, but in neither case was the lock destroyed.—Editor.]

"At about 7.45 a. m., November 10, 1909, four vessels had entered the Poe lock bound down, and the operators had started to close the upper service gates. The steamer *Isaac L. Ellwood*, 478 feet in length and loaded with about 8,000 tons of ore, had been moored some distance above the lock, and started to place herself in position for the next lockage. She was moving slowly when there was the usual misunderstanding between captain and engineer. Instead of reversing the engines, they were driven forward. An attempt was made to stop the boat by lines to the shore, and three steel cables were parted without checking her progress. The

southern gate was about two-thirds closed when the vessel struck it, severing the operating cables and driving it against the miter sill, where it brought the boat to rest, without injury to the miter sill or the system of anchorage; the gate itself was, however, badly strained, and twisted, and both the air and water compartments had to be caulked and the holes of sheared rivets plugged before the gate could be floated. We are now attempting to replace the gate by one of the upper guard gates, but are having trouble with the gudgeon pin at the heel on account of rust.

“I know of no particular feature of this accident of sufficient interest for publication in the PROFESSIONAL MEMOIRS. The enormous resisting power of the gate without being mitered has impressed me as the most striking feature.”

The creation of a corps of civil engineers to have charge of the rivers, harbors, and other works of civil character is a project that seems to have great attraction for some minds. There is before Congress at the present time a bill for this purpose. Without attempting here a full discussion of this subject, a few considerations may be briefly mentioned which afford food for thought.

Certain civil works were placed under the charge of officers of the Corps of Engineers at a time when that corps was the only body of scientifically trained engineers in the country. The results of this charge are too well known to require further mention, and a successful method of administering public improvements is not to be lightly changed without careful investigation or without a reasonable certainty that the change will result in improvement in some respect.

Would the execution of the work be improved? Civil engineers to succeed the officers of the Corps would have to be selected in accordance with the Civil Service law, whose principles have already been observed in the selection of the present officers to a much greater extent than they could possibly be applied to the proposed corps. How, then, would a better body of engineers be obtained? Do any of the many excellent schools of engineering throughout the country graduate engineers thoroughly instructed in the improvement of rivers and harbors? All the experience of the past century is the heritage of the present officers and is imbibed by them through their frequent changes of station and duty. Is there any other class of engineers in the country to-day that can

claim a superior or comparable training in this branch of engineering?

Could the proposed corps be composed of assistant engineers who have received their training through actual experience on the works? Among these men are many excellent engineers whose intimate knowledge of the individual operations upon which they are employed makes their services invaluable. But would it be fair to them to take them from the work which they know so well (harbor work, for instance) and charge them with duties of a different nature (say, river improvement)? How are selections to be made from them? Will they subject themselves to such rigid examinations as the present officers are required to undergo? Is it at all certain that among them could be found a sufficient number whose experience has been broad enough to meet the requirements of the new corps who would voluntarily subject themselves to the frequent changes of station and duty which will always be necessary in such a corps?

Is it wise, then, to expect that a new corps can be created with a reasonable certainty of improvement in the quality of the work?

Would the creation of a new corps result in economy? The present corps may be divided into three classes: officers performing purely military duty, officers on military duty who also perform civil duties, and officers on purely civil duty. The first class would not be affected by the establishment of a new corps. To take their civil duties from the second class would simply reduce the amount of service obtained by the Government in return for the salaries paid to such officers, and would necessitate the employment of a considerable number of engineers to relieve them of their civil duties. The third class might be replaced bodily by the members of the new corps, but no material reduction in cost could be thus secured; for it will be found on examination that the proposed corps provides for more engineers than there are at present officers engaged on purely civil work, and men of equal ability will demand at least equal salaries.

What would be done with the officers displaced? Would they be put out of the service? Would they be retained in idleness? Would they be absorbed by the new corps? Or would Congress organize new bodies of engineer troops for them to command? It should be noted that many of the men in question are of high rank. In any case, where does the economy appear?

Would the military engineer service be improved? The only

way to utilize all of the officers for military engineering duties would be to organize a number of new battalions, and this will hardly be possible on the necessary scale.

The Corps of Engineers might be cut down to a size just adequate to furnish the officers for the desired number of battalions; but the entire present corps can furnish less than one-half the officers really required in case of war with a first-class power. A war of serious magnitude would probably cause the suspension of civil improvements. What would be done then with the members of the civil corps? Could they be utilized as military engineers? The military engineer can not be improvised from the civil engineer; his art is a special branch of engineering involving a broad knowledge of all military art and its relation to the principles of civil, mechanical and electrical engineering. Moreover, it is an art steadily growing in importance and complexity. The present arrangement appears to be the only practicable means by which an adequate corps of military engineers can be maintained in time of peace or be available in time of war.

But suppose that it *were* possible to keep all engineer officers on purely military duty. Is there any way in which they could be provided with real military engineering practice in time of peace? Actual engineering practice is essential to fit them for the field. Drills, practice marches, problems (so-called) and all similar instruction will always be as futile to really fit them for large operations in the field as would playing with imitation money be to develop financiers. The strength of the Corps of Engineers to-day is the result of the century of experience in the actual solution of real engineering problems and the bearing of grave responsibilities.

Again, would the best of our officers remain in the service if they were to be restricted to the peace operations of the purely military engineer? Would not many resign to engage in the practice of their profession in civil life? What holds our best men in the service to-day? Those who have resigned in the past have, as a rule, benefited by the change. Why should they not resign and obtain appointments in the new corps, where they could follow their profession as engineers, draw equal or greater salaries and be relieved of the burdens of military service? Would Congress debar from the new corps the men best fitted for it?

The above are some of the questions which should be answered satisfactorily before a radical departure is made from an established system which has for a century proved successful.

NEW LOCK AND DAM NO. 5, MONONGAHELA RIVER AT BROWNSVILLE, PA.

BY

LIEUT. LEWIS M. ADAMS
Corps of Engineers

Lock and Dam No. 5 is the fifth unit in a series of fifteen dams giving slackwater navigation on the Monongahela from Pittsburg Harbor to above Fairmont, W. Va., distant 127 miles from Pittsburg and almost directly south from the latter city geographically. As is well known, the Monongahela taps the richest bituminous coal region in the world and with its canalization by the General Government now offers itself as a public highway independent of the seasons, genuine or alleged freight car shortages and railroad common stock needing a dividend.

The work is typical of modern methods in design and construction and is now rapidly nearing completion and will soon take the place of old Lock and Dam No. 5, which latter structure is becoming unserviceable due to the ravages of many winter floods, the increased demands of an expanding river commerce, and the necessity for enlarged lock capacity to accommodate bigger fleets at one lockage.

The limiting cost of the new work was fixed at \$756,042 by the River and Harbor Act of March 2, 1907, and appropriations were made as follows: March 2, 1907, \$256,042, authorizing additional work to the amount of \$500,000; Sundry Civil, May 27, 1908, \$300,000; Sundry Civil, March 4, 1909, \$200,000; total, \$756,042.

A board of officers to design the work was convened by the District Engineer Officer soon after the Act of March 2, 1907, was passed, and on September 16, 1907, a contract was entered into with H. E. Talbott & Co., of Dayton, Ohio, to construct the lock on a unit cost basis, according to blue-print plans accompanying the specifications. The abutment and dam were to be built by the United States by the "hired labor" method.

The board of design consisted of the following officers of the Corps of Engineers: Capt. F. W. Altstaetter, senior member, to

design the lock; Capt. E. M. Adams, to design the dam; First Lieut. E. N. Johnston, to design the abutment.

Later on Capt. A. E. Waldron was appointed on the board to assist Capt. Altstaetter in design of lock, gates and operating machinery.

The following conditions were imposed by the order appointing the board:

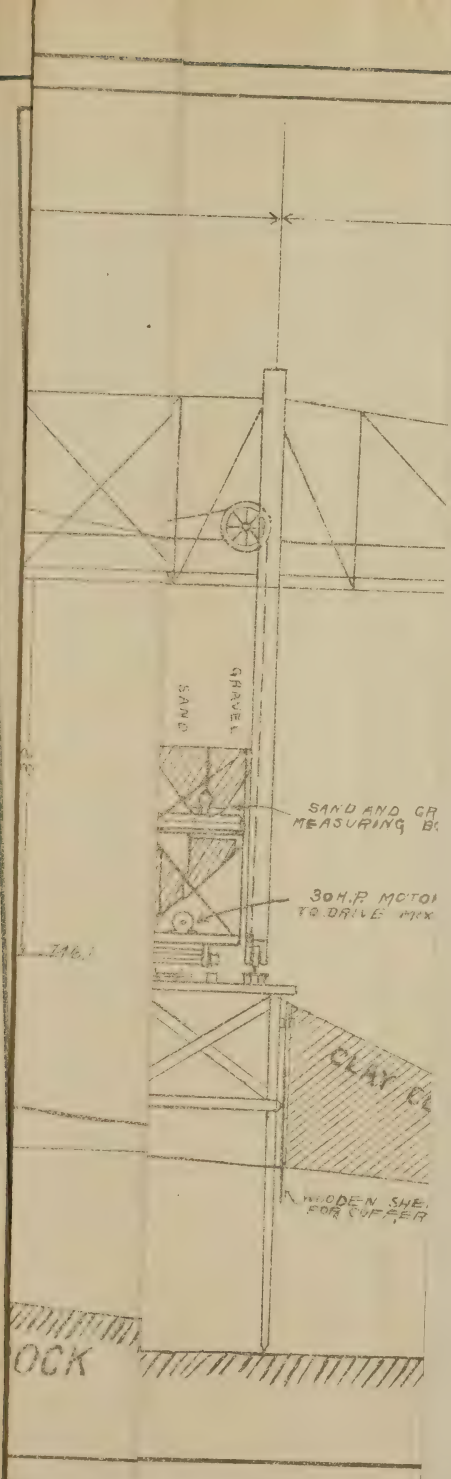
1. To be a fixed dam with normal elevation of upper pool 747.1 feet above sea level, which may be increased to 750.1 by raising a movable top on the crest of the dam. Level of normal lower pool 735.1, thus giving a maximum lift of either 12 or 15 feet, depending on whether the movable top is down or up.

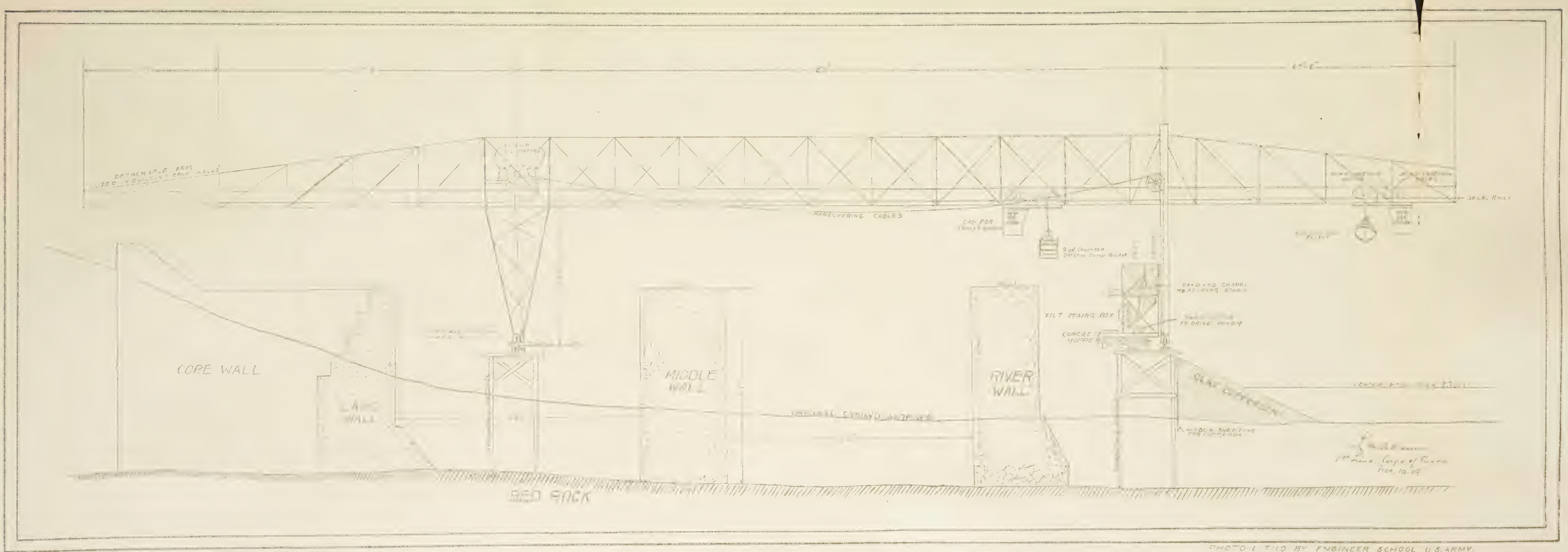
2. To be a double lock, each chamber 56 by 360 feet in the clear, with an intermediate set of gates in one chamber; the old lock is a single chamber 50 by 190 feet.

3. Lock gates to be of the mitring type.

4. Location as previously decided upon and shown on final drawings.

It may be of some interest to know why the site was chosen at the town of Brownsville, 57 miles up river from Pittsburg, and 2 miles below the old lock which it replaces. The new dam occupies one of the narrowest parts of this section of the river, which is a disadvantage as to spillway capacity, but on the side of economy is compensated for to some extent by the high, steep banks and convenient depth to firm bed rock existing at this location. An ancient covered highway bridge carrying the old National Pike (St. Louis to Washington), crosses the Monongahela at Brownsville, and although this old structure has been condemned and ordered raised by the Secretary of War, the private holding company is fighting its modification by appeal and otherwise, and to date has been successful in maintaining this serious impediment to navigation. This condition of affairs had to be considered, and the dam was located above this bridge and the town. At first glance it would seem that the town wharves should have the benefit of the increased depth in upper pool, but other opposition to the lower location arose from those interests that feared great flood damage with the dam below town. No argument that the dam would be drowned out and its effect gone at extreme high water could convince the skeptical owners of riparian property. Between the location of the new dam and





the old dam the river bends and with lower banks offers poor sites for the lock and abutment.

The Monongahela River at Brownsville has a slope of about 1 foot per mile and an extreme low-water discharge of 150 cubic feet per second, which would reduce the river to a creek barely able to float a rowboat were not the river slackwatered. Extreme flood heights of 35 feet have occurred, but steamboat navigation becomes unsafe on account of bridges when floods get above 9 or 10 feet.

Such considerations enabled the primary conditions to be established as follows:

a. Lower guard sills to be at elevation 726.6 above sea level, so as to give 8 feet navigable depth over miter sills at low water or normal lower pool elevation 735.1, the miter sills being 0.5 feet below guard sills.

b. The necessary lift to be 12 feet to give navigable depth over lower sill at Lock No. 6, 12 miles above. This allows the proper elevation of upper miter sills to be fixed at 738.1, and as navigation ceases with flood heights of 10 feet, a safe elevation for the top of the lock walls would seem to be attained if fixed at 759.1, thus allowing the lock to be operated by hand with safety until drowned out.

H. E. Talbott & Co., who were the successful bidders for the erection of the lock walls, gave pleasing evidence of being alive and on the job from the date the contract was awarded. They at first figured on doing the work with two radial Lidgerwood cableways suspended across the stream, but the presence of the town with its closely built up river front convinced them that they would have to abandon their old favorites and they commenced upon an alternative scheme without delay.

The amount of concrete to be placed in the lock walls (56,000 cubic yards) was of course the determining factor in their bid and was of sufficient magnitude to warrant the purchase of a first-class new plant. With the assistance of the designing engineer of the McGeorge Engineering Co., of Cleveland, Ohio, who built the plant, the following novel scheme was devised. All the heavy work would be done by two immense gantry cranes, built of structural steel with extensible cantilever arms, traveling on two tracks of 80-pound rails, 1,250 feet long up and down stream and spaced 150 feet apart. Each track is supported at elevation 746.1 upon pile trestles, requiring about 1,200 piles for erection. The shore rail ran along

the median line of the land chamber, while the river rail ran 30 feet outside of and parallel to the river lock wall; thus the cranes spanned half the land chamber, the middle wall, the whole river chamber, and the river wall, while the shore cantilever arm reached over the land wall and two core walls. Each crane carries traveling trolleys of 7 tons live load capacity, from which are operated the $1\frac{1}{4}$ -yard orange peel excavating buckets, 2-yard clam shell bucket, 2-yard bottom dump concrete bucket, chain tongs, etc. The river pile trestle also carries tracks for a traveling 1-yard Smith mixing plant (electrically driven), and a narrow gauge track for a 15-barrel motor driven cement car.

The mixer was located on the river side of the work because the sand and gravel would all be delivered by river in fleets of 100-yard flats. These were unloaded into the bins above the rotary mixer by a 2-yard clam shell bucket operated from a trolley, while a second trolley on the same crane operated the concrete bucket, carrying the batches to the forms. In this manner the whole operation of mixing and placing the concrete was accomplished by one crane, requiring only a motorman for each trolley, five men on the mixing plant, and two men on the motor-driven cement car; the second crane was free to do excavating, set heavy forms, move the electric pumps, etc.

In designing the crane trusses, the dead load was assumed at 450 pounds per lineal foot, wind pressure 30 pounds, live load due to trolley, buckets and material 27,000 pounds. The ends of each crane truss are supported 32 feet above the rail by two built-up steel legs, the latter rest on truck beams borne by six extra heavy double-flanged car wheels. Each crane is given translating movement along the 80-pound rails by two 50 horse power General Electric direct-current motors, which drive two large drums; this mechanism being mounted in the truss of each crane above the shore legs. The drums wind and unwind two $1\frac{1}{4}$ -inch steel cables laid upon the ties beside each of the 80-pound supporting rails; both cables are anchored fast at each end.

Each trolley is given lateral motion upon 30-pound rails along the crane truss by a 30 horse power direct-current motor carried with the trolley. Each trolley handles its load with a double-drum two-line hoist driven by a 50 horse power direct-current motor, also carried with the trolley. The entire mechanism of each crane is under the absolute control of one motorman in the cab of the trolley; as he is able to watch his own work from directly overhead,

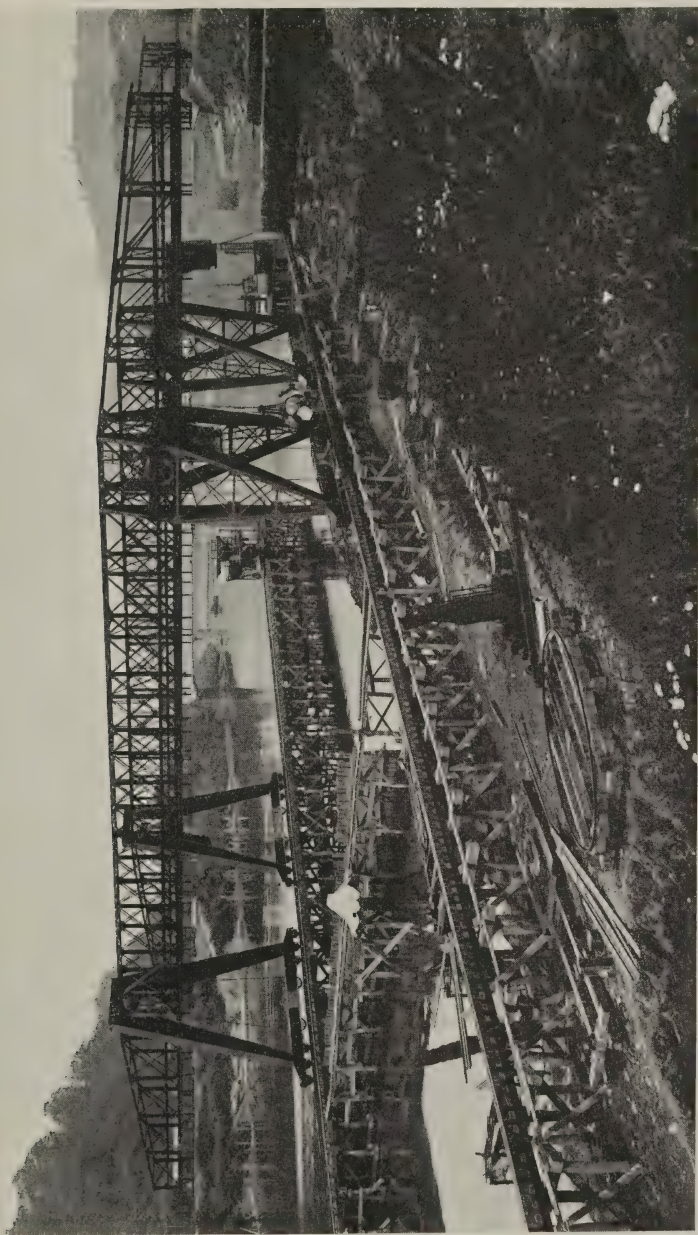


Fig. 1. Gantry Cranes used in constructing New Locks and Dam No. 5, Monongahela River.

no signalling is necessary, and accident liability is reduced to a minimum. The contractor, however, carried a general accident policy to protect his company against liability for damages resulting from any accident on the site of the work.

MIXING PLANT

The framework of the mixing plant is of structural steel carried on six double-flanged wheels, running on tracks of 65-pound rails with 8-foot gauge. This mixer is attached to the river legs of a crane by detachable bars and is moved with the crane on parallel tracks. Sand and gravel receiving bins are located over the hopper of the mixer, and these bins have measuring boxes at their bottoms with power cut-offs. The gravel box holds just 24 cubic feet, as specified in the contract; the sand box, 11 cubic feet of sand, as specified; and the cement measure holds exactly 380 pounds of cement; these quantities make a 1-yard batch very closely. A Government inspector was always on the mixer when it was running, and this proved eminently satisfactory to both parties interested, as it did away with all disputes as to the quality of the concrete furnished.

The mixer is a "Smith Improved 1-yard," driven by a 30 horse power direct-current motor. A batch hopper was built below the spout, and when one batch was mixed it was dumped into this hopper, the mixer immediately continuing to mix another, so that by the time a trolleyman returned from the form and placed the concrete bucket beneath the hopper, both single batches were ready for the concrete bucket of 2-yard capacity.

All cement for the lock was American Giant Portland, shipped from Bethlehem, Pa., in box cars in bulk, no bags or barrels. The cement is unloaded from a siding directly into a shed specially constructed with four 600-barrel bins. Beneath these bins runs the narrow gauge track which carries the 15-barrel cement trolley car, the latter using 5 horse power from a third rail. This narrow gauge track leads out from the shed to the river pile trestle which supports the mixer coupled to the river legs of a crane. At the mixer is a bucket elevator to raise the cement from the car to a storage bin beside the sand and gravel hoppers.

This concrete plant has mixed and placed 32 cubic yards per hour for eight consecutive hours.

All electric current used on the work was purchased from a local power station of the West Penn Electric Co., who furnished alternating current at 2,200 volts to the contractor. The latter rents a

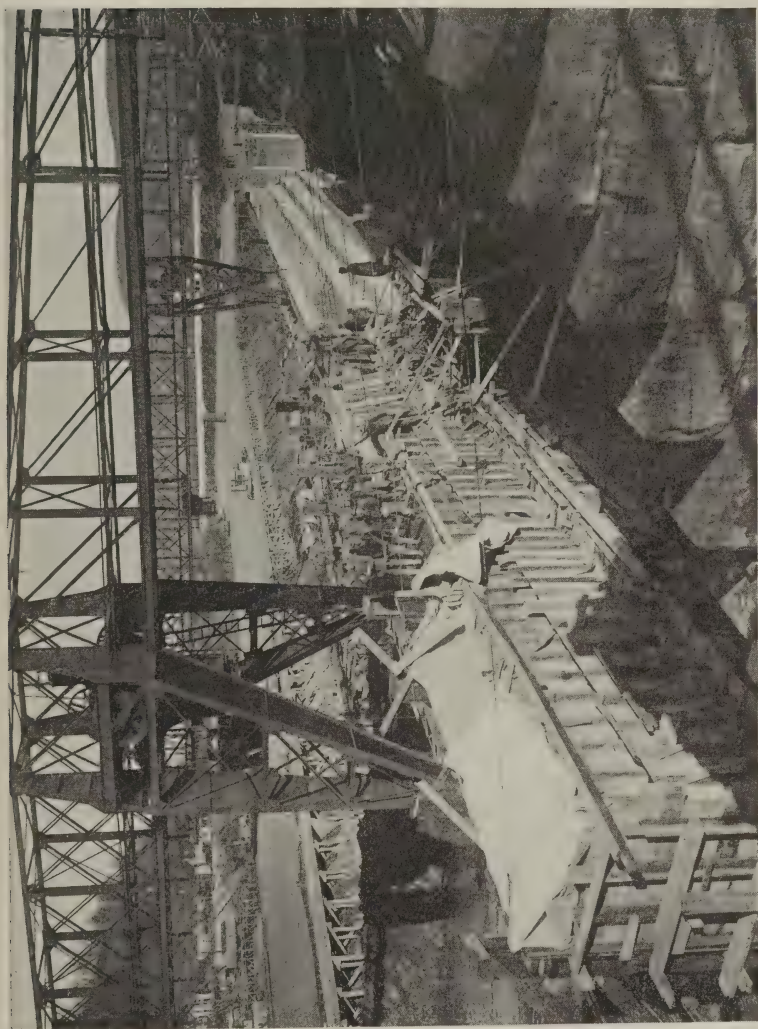


Fig. 2. Showing cranes, forms, lock wall, and general layout of locks.

150-kilowatt Westinghouse motor generator set and uses direct current from it at 550 volts. The price paid by the contractor is 2 cents per kilowatt hour metered on the alternating current line, thus requiring him to pay for all his own losses due to operating the motor generator set without load on the direct current side. The rental for the set is \$50 per month.

The site of both lock chambers was enclosed in a single large cofferdam 175 by 710 feet, constructed as follows: Double waling pieces 8 by 8 inches were bolted to the outside of the river pile trestle, and between these waling timbers were driven 6 by 10 inch by 20-foot hardwood sheet piling, with tongue-and-groove strips spiked to the edges, thus making the piles 12 inches instead of 10 inches wide. This sheeting was banked on each side with clay excavated from the site of the land wall. The 175-foot ends of the coffer were similarly constructed. The cofferdam proved practically water-tight all around, but much water entered the workings through a 10-foot stratum of gravel overlying the bedrock foundation upon which the walls were erected. To keep the coffer unwatered, three 40 horse power 10-inch submerged electrically driven centrifugal pumps were necessary, each pump capable of discharging 3,000 gallons per minute over a head of 28 feet. Each pump was directly connected to a vertical driving shaft 30 feet long, obviating the necessity of removing the motors at every high-water stage flooding the coffer. For the foundation work it was found convenient to also install 40 and 60 horse power steam boilers to operate two No. 5 pulsometers and one No. 2 6-inch Emerson pump. The steam pumps simply removed the water from places where it was inconvenient or uneconomical to set up one of the large electric pumps.

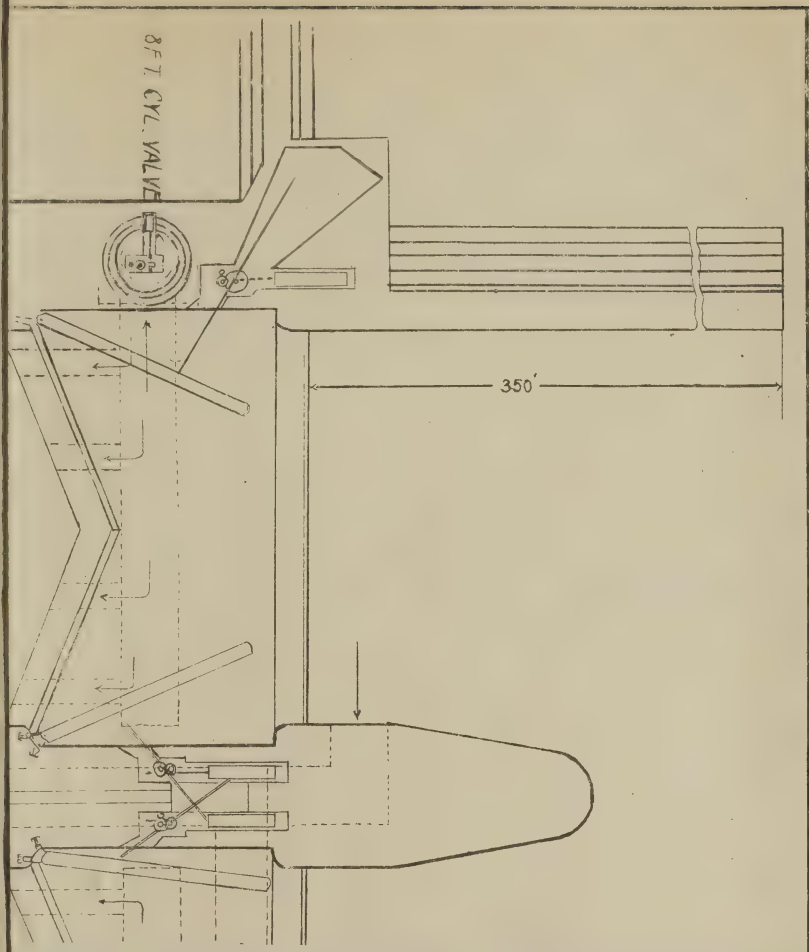
The cranes were put in operation June 1, 1908, and worked almost continuously night and day until August 20, 1909, when power was shut off and a contract let to a wrecking firm to dismantle them. During this period the following work was accomplished by them:

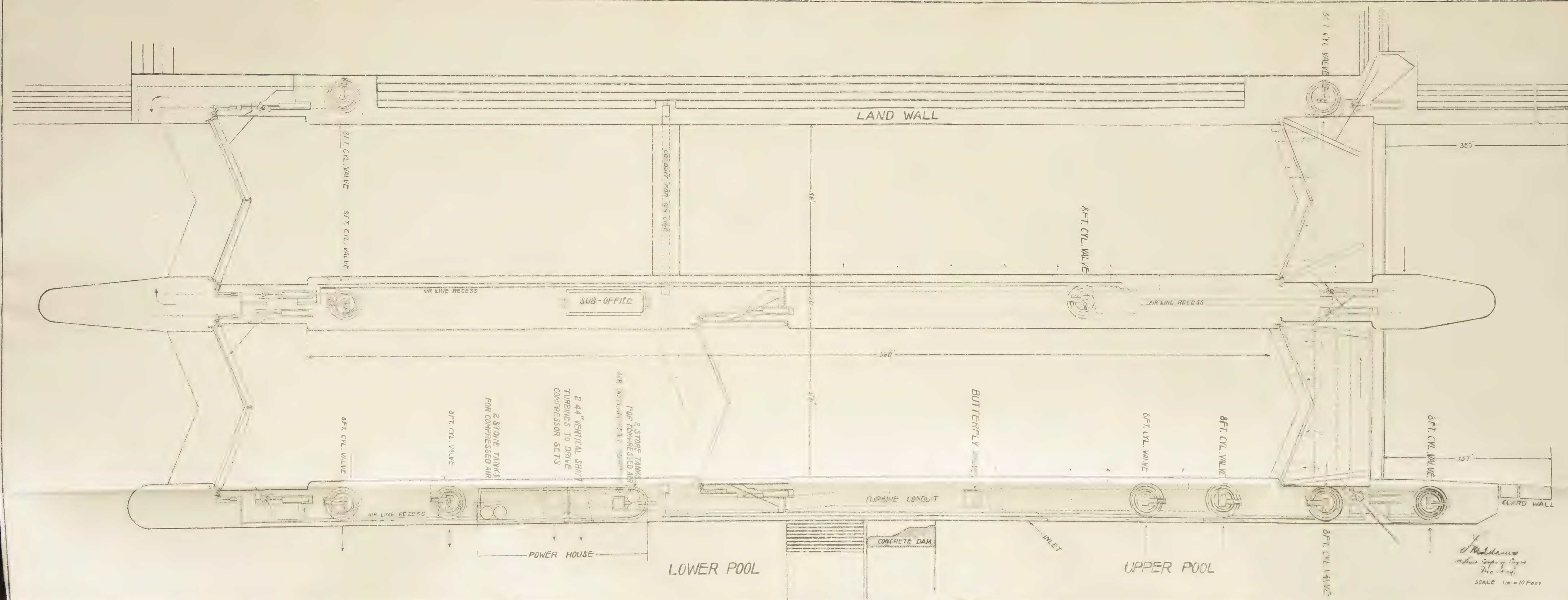
September 15, 1908.—Excavation of land and guide walls completed; 27,000 cubic yards.

November 15, 1908.—Concrete in land and guide walls completed; 21,630 cubic yards.

November 20, 1908.—Excavation for middle wall was completed; 11,560 cubic yards.

May 15, 1909.—Concrete work in middle wall completed; 15,290 cubic yards.





December 31, 1908.—Excavation river and guard walls completed; 9,450 cubic yards.

July 5, 1909.—Concrete work in river wall was completed; 13,962 cubic yards.

July 10, 1909.—Excavation for sills and core walls, etc., completed; 8,040 cubic yards.

July 11, 1909.—Concrete in the sills and core walls, etc., completed; 5,027 cubic yards.

A summary of the work accomplished by this plant in the fourteen months from June 1, 1908, to July 31, 1909, is given below:

Kind of work	Quantities	Contract Price.
Earth excavation.....cu. yds.	56,270	\$0.50
Rock excavation.....cu. yds.	546	2.00
Earth back filling.....cu. yds.	17,660	.30
Concrete—1:3:6 mix.....cu. yds.	55,916.5	6.50
Wooden round piles.....lin. ft.	12,195	.50
Placing of metal.....lbs.	35,000	.02

The contractor stated that his total labor account with the plant described amounted to less than 25 per cent of total expenses.

It may be of interest in passing to note some of the general features of design of the lock.

The land lock measuring 56 by 360 feet has no intermediate gates as the river lock has; it is filled from the forebay through openings in the concrete upper miter sill and through seven 4 by 5 foot openings leading from a conduit in the middle lock wall. The latter conduit is partly filled from the forebay and also has a connection to the river side of the river lock wall by a branch carried as an inverted siphon under the upper guard sill of the river chamber. This somewhat unusual construction is undertaken in order to allow the land lock to be filled without drawing too heavily on the forebay; thus when much floating ice is collecting above the lock in winter it is not carried into and behind the lock gates, as it otherwise would be if this chamber were filled entirely through the openings under the miter sill. To open the upper gates there should be practically no head against them, and there would be a head of a few inches if there were no connection with the forebay. This small difference in head is thus accounted for: the river surface at the crest of the dam where the velocity is great is lower by several inches than the surface a short distance upstream; between these points the surface has an appreciable slope, and as one conduit to

the land lock and two conduits to the river lock have their intakes at points opposite this sloping river surface, the filling water enters these conduits at a trifle less head than the filling water from the quiet forebay. Hence it is seen that to avoid having a small head against the upper gates on opening them, water must be admitted from the forebay to overcome it.

The river lock also measures 56 by 360 feet, but is fitted with an intermediate set of gates, which when closed divide the lock into two chambers. In this way it is possible to economize water during dry seasons by locking single vessels or small tows through the upper chamber. No floors were built in the lock chambers, as the walls rest on bedrock. The conduits in the walls were necessarily large, so it was deemed wise to install 8-foot cylindrical valves and not the butterfly type. Each valve can be operated by a compressed air engine or by hand; the gates are opened and closed by compressed air with an ingenious but simple rack spar device sunk out of the way in the lock wall; hand power can also be used. Butterfly valves in the lower gates facilitate the emptying of the chambers and compressed air furnishes the power for their operation also; each lock is also provided with two 8-foot cylindrical valves for emptying.

Compressed air is generated in a power-house on the river wall. Two 44-inch turbines drive two individual air compressor sets, each set capable of compressing 300 cubic feet of free air per minute to 100 pounds pressure when operating under a head of 8 feet.

The lock gates are built of structural steel, horizontal members continuous 24-inch I-beams, the reactions being the pinch at the miter posts and the thrust at the hollow quoins. The sills are built strong enough to take the load if the gates do not miter, but this is not the design.

The lock walls are all built of concrete resting on bed rock. In computing wall sections, water was assumed on both sides to rock foundation, though ordinarily mud would be found near the bottom. The center of pressure in a wall at any horizontal section was not to fall outside the middle half at such section nor the pressure on the base to exceed 150 pounds per square inch. The land wall was designed somewhat heavier than the above, because it was surcharged with a railroad embankment. The limiting length of monoliths was 40 feet. Many of the wall sections through valve recesses are not stable, but the monoliths containing such sections are stable.

Wall sections were given sufficient strength so that any one of the three chambers might be pumped out to elevation 724.1 with water



Fig. 3. Showing general view of locks, dam and abutment. First five sections of dam completed.

in upper pool not above 752.1 and in lower pool 744.1, the chambers not pumped out having any level of water between these limits.

Concrete was assumed to weigh 140 pounds, or .07 ton per cubic foot.

In wall calculations weights of valves, water in conduits, machinery, etc., were omitted as being on the side of safety.

Gates were designed to miter at 70-degree angle to median line of lock chamber.

From a study of gauge records, a lower pool level of 744.1 was assumed to correspond to an upper pool level of 752.1; thereafter 1-foot rise in upper pool was assumed to correspond to 1 2-3 foot rise in lower pool until the dam becomes drowned out.

Chambers are designed to be coffered off when necessary by use of needles, whose bottoms rest against guard sills and tops against a heavy steel I-beam spanning the lock and reinforced with timber struts. The outer lock was built with intermediate gates, because large tows needing a whole lock chamber can get to the inner lock more easily than to the outer.

These intermediate gates are not installed until the dam is completed and both locks are in operation; the river lock is then unwatered, the high upper gates are moved to the intermediate gate recesses, the upper miter sill is raised and permanent short upper gates are installed.

In the design of the walls a departure was made from the teachings of many writers when it was assumed that sections were safe if the resultant of forces acting fell within the middle half. In these walls (except the land wall) the pressures are due to water only, and can be determined with a certainty not at all possible in designing ordinary retaining walls; moreover, as the walls are of 1:3:6 monolithic concrete and not built of blocks, considerable tensile strength might be allowed in designing the sections.

Running upstream in continuation of the river wall is a heavy concrete guard wall to assist tows in making the river lock and to prevent them from being caught in the suck of the dam and carried over it, as happened to a steamer a few years ago at another lock on the Monongahela.

The turbo-compressor plant is to operate with a minimum head of 4 feet, the turbines having submerged draft tubes. The turbines are of the vertical shaft type, and the penstock is a large conduit in the river lock wall carrying water from an intake 30 feet upstream from the back of the dam.

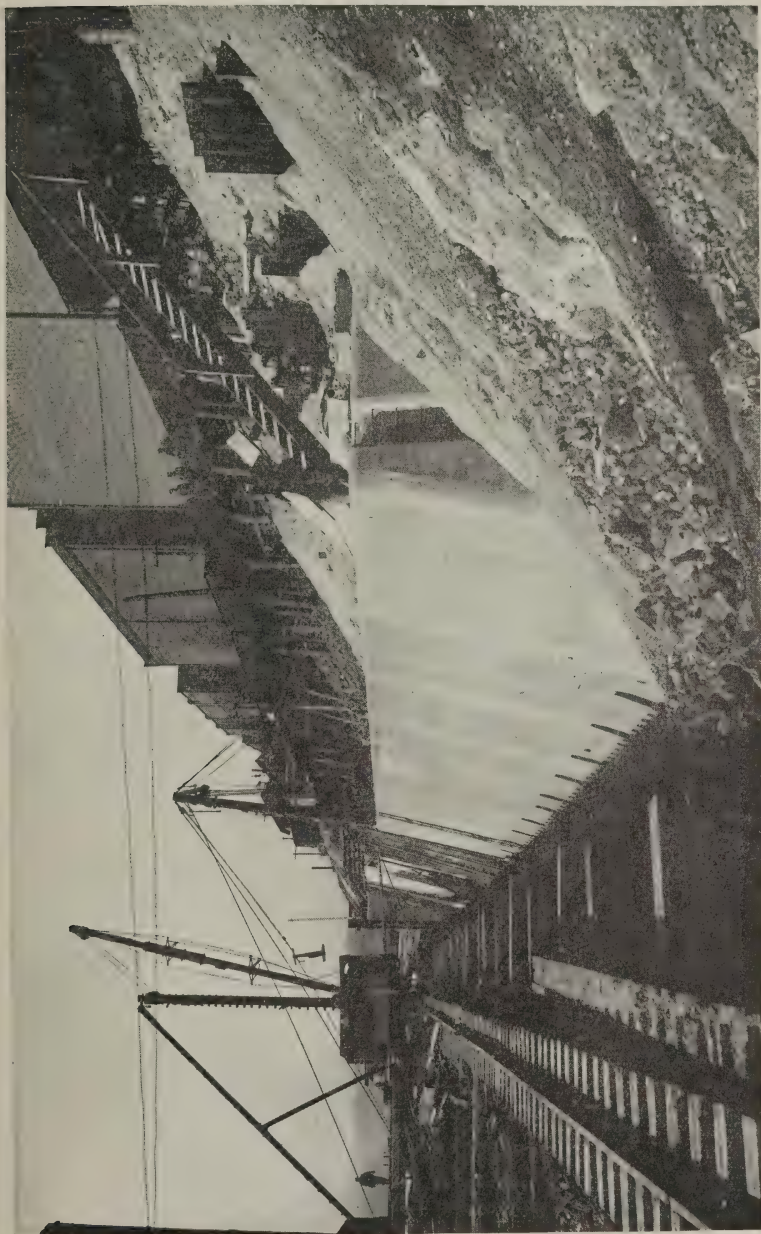


Fig. 4. Showing abutment and pile driver and gin pole used in construction.

The lock gates were purchased under a separate contract with the Pittsburg Bridge and Iron Works of Rochester, Pa., the contractor to erect the gates in place and the United States to keep the chambers unwatered for sixty days while erecting.

The valves and valve machinery, the rack spar machinery, etc., were purchased under a separate contract with the J. & J. B. Millholland Co. of Pittsburg, Pa., the United States making its own installation.

The air compressing plant was purchased from the Hall Steam Pump Co. of Pittsburg, Pa., the Dayton Globe Iron Works subcontracting for the turbines.

THE ABUTMENT

The abutment was to be constructed by the method of "hired labor." Assembling of plant for this purpose was begun early in 1908, and about the middle of August, 1908, actual work began.

The abutment for new Dam No. 5 was originally designed to contain conduits and cylindrical valves to operate in conjunction with others in the river lock wall in raising and lowering by hydraulic pressure a Chittenden drum weir movable top like the ones now installed at Dams Nos. 2 and 3, Monongahela River. For various reasons it was deemed advisable by the district engineer to abandon the drum weir idea for movable top, and to substitute a much more simple and less expensive type of hinged iron flashboards to accomplish the same object; *i. e.*, to obtain an additional head of 3 feet above the dam to facilitate navigation during extreme low-water periods.

The necessary authority having been obtained from the Chief of Engineers, the abutment was redesigned without conduits or valve recesses, Trautwine's method for surcharged retaining walls being used.

The river at the selected dam location being quite narrow, it was necessary to build the abutment as far back in the steep river bank as other limiting conditions would permit, thus preserving as large a river cross section as possible and as a consequence permanently reducing flood heights and river current at this location.

Local conditions made the construction of the abutment at this point a task requiring considerable study, and several plans were carefully considered. The difficulties to be overcome were:

First. The main line of Monongahela Division of the Pennsylvania Railroad passes by the abutment at elevation 776.5, with the



Fig. 5. Near view of plant used in building abutment.

center line of track only 20 feet back from the top of the wall. Elevation of top of wall 762.1 for 60 feet, 759.1 for 188 feet.

Second. Two large brick bonded warehouses of the Thompson Distilling Co., one of eight stories and another of ten stories, stand on the river bank just back of the railroad track. These buildings were very poorly constructed and caused much apprehension from the first. The ten-story warehouse began to crack badly about the second month of the work, when we had gotten nearly by it.

Third. The bank to be held during construction, consisted of soft, flowing, blue and yellow clay underlaid with a stratum of compact gravel and all resting on the rock, steeply sloping to the river.

The general dimensions of the abutment were made large, the distance that it extended upstream from the back of dam being 30 feet and below the toe of the dam 210 feet, both measured along the bed-rock foundation at elevation 715. This made the abutment a heavy retaining wall 21.5 feet wide on bed rock, 47 feet high, 4.5 feet wide at top and 265.5 feet long over all, stepped on the back and with sloping face battered at 5 on 1. Two core walls were also built into the bank at each end, the upper core wall reaching back 23 feet into the bank and the lower one 17.5 feet.

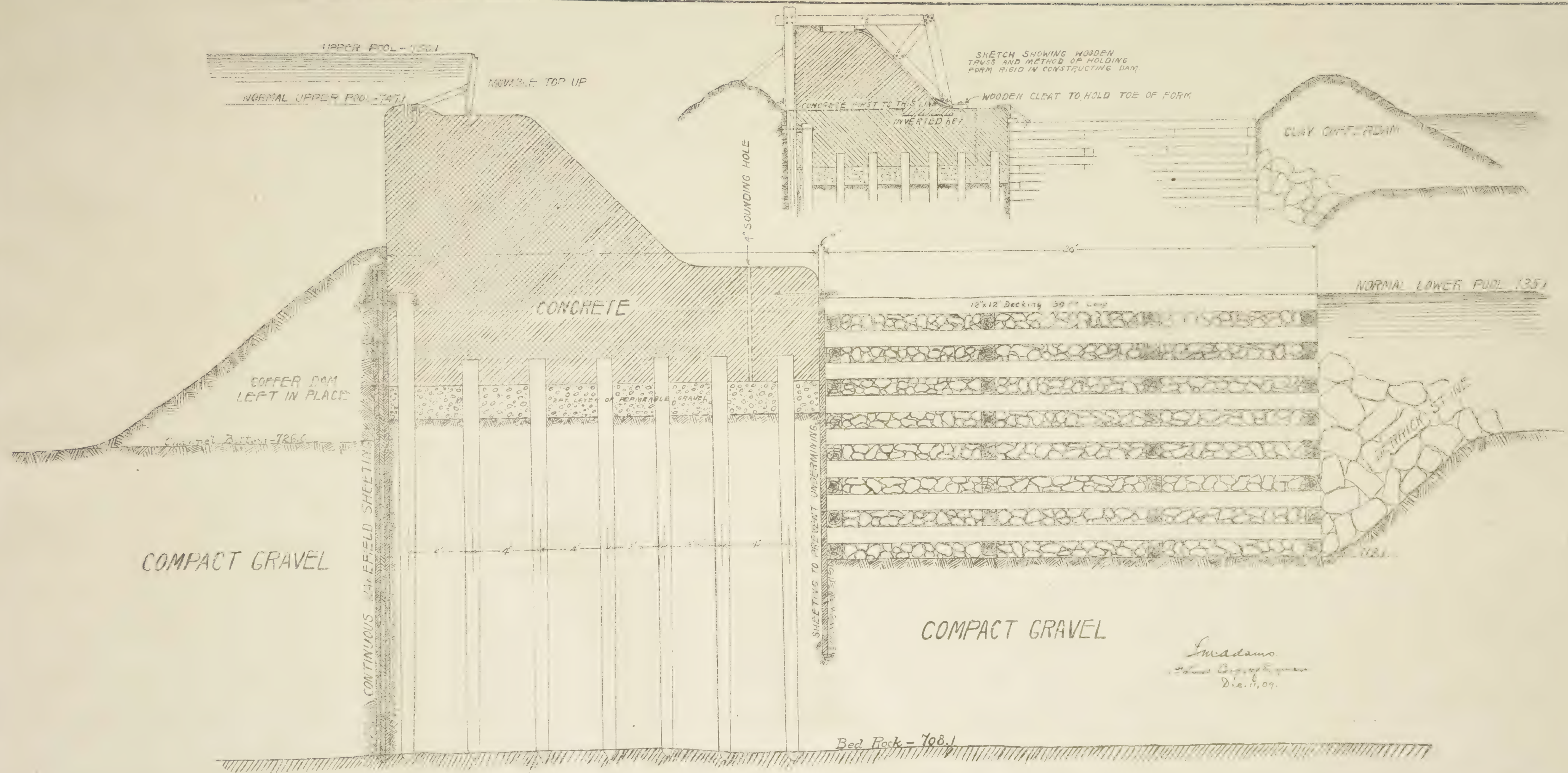
The plan of construction adopted was as follows:

The excavation was to be done within two lines of interlocking steel sheet piling driven to rock, the row of piling on the river side being driven with steam hammer to elevation 718, approximately, and the inner row part way up the steep bank being driven the length of two piles deep; a 20-foot pile alternating and breaking joints with a 25-foot pile. The depth reached by this row was approximately at elevation 721.0.

The excavating was done with a three-fourth-yard orange peel Hayward bucket operated from a traveling derrick which ran upon two tracks of 60-pound rails located on the river side of the site, and supported on pile trestles, the gauge being 45 feet, the height of the mast 45 feet and the boom length 80 feet. A three-drum hoist furnished the power, with a separate steam swinger. Steam was generated in a 50 horse power horizontal boiler using natural gas as fuel, which also furnished steam to the steam pile hammer, to the pumps within the coffer and to the pile-pulling engine.

Excavation was begun on the first 60-foot section of the abutment on August 15, 1908. The material removed was piled on the river side of the work to form a heavy cofferdam and to brace against. It

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was manifest from the first that the heaviest kind of bracing must be used to support the steep inner bank with the superimposed railroad and buildings.

When the excavating was about to be commenced, a conference was held between the railroad division superintendent, the owner of the distillery and the officer in local charge for the United States to arrive at the most practical scheme that would allow all parties interested to continue operations with the least danger to all concerned. It was decided mutually that the railroad would, at its own expense, move its line back 15 feet, close to the distillery warehouse,

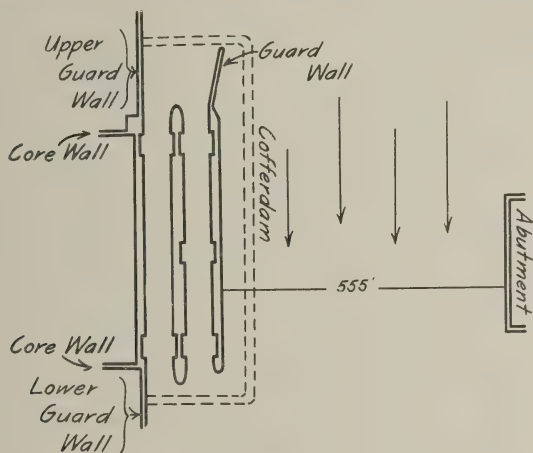


Fig. 6. Stage of operations March 30, 1909. Lock about completed, abutment completed. Ready to begin pile driving in first section of dam.

and maintain itself there until the completed work allowed it to resume the old location. The line of the railroad along the river bank was permitted to overrun the official harbor line at this location, as there was no other way to pass unless the Thompson Distilling Co. sold off parts of its property, with buildings, for right of way. A high hill behind the distillery property cut off any other practicable route for the railroad. It was verbally understood that the United States would use all reasonable care to prevent any slips or cave-ins, that the work would be prosecuted as rapidly as it could economically be done, that the railroad would keep a track gang on hand for maintenance and run at slowest speed by the site, and that if any of the warehouses were cracked and damaged without its being obviously due to carelessness or bad judgment, the railroad company must be held responsible. It was only by the consent of the

other two parties that the railroad could get a right of way past the point.

The bracing used consisted of six tiers of 12 by 12 inch timbers spaced 7 feet vertically and 15 feet horizontally. As the pressure from the inner bank soon began to cause the 12 by 12 inch timbers to bow out, they were all reinforced on each side by 6 by 12 inch timbers, and all corners were strengthened by a 12 by 12 inch knee brace. This heavy bracing proved entirely satisfactory, and no slides, cave-ins or other serious embarrassments occurred.

As soon as the bed rock was reached, it was cut down level and concrete work began October 10, 1908. Work continued night and day in this manner, opening up 60 feet at a time until the entire abutment wall was completed on January 25, 1909. The core walls were next begun, and finished on April 13, 1909. The water was removed from the workings by a single No. 3 Emerson pump, which rendered satisfactory service with few repairs until the work was completed. It may be noted that the secret of success with an Emerson is plenty of oil.

The sheet piles were pulled and driven over and over again, although some piles had to be straightened before being redriven. The straightening was done by dropping a pile hammer, held in a land pile driver, on the bent portions, the method proving inexpensive and very satisfactory. Much difficulty was first encountered in pulling the steel sheet piles, especially those which were driven two deep with a plated butt joint connection. A heavy A-frame gin pole 35 feet high was built and rigged with quintuple steel blocks to carry a three-fourth-inch steel line. This rigging always either pulled the pile or tore out the metal above the point of attachment. Cold rolled steel shafting $1\frac{3}{4}$ inches in diameter was the only material hard and tough enough to answer for pins to use with the heavy shackles. A triangular forged steel ring was attached to the lower tackle block and on the ring hung two heavy shackles or clevises. Two holes were punched, with a hydraulic punch, in the top of each pile and both clevises pinned to the holes; an 8 by 10 inch hoisting engine would then jerk on the steel fall line with full speed and steam pressure. This usually started the pile. The pull required on many piles driven to rock and in contact with concrete was often over 60 tons. The concrete was prevented from adhering to the steel piles by using tar paper to separate the surfaces.

The material through which the double depth piles were driven was first a stratum of yellow clay 13 feet thick, then 16 feet of blue

clay, then 8 or 10 feet of very compact gravel. Experience proved that the steel sheet piles, with five-eighth-inch web, were somewhat light for double depth driving through gravel; many piles were bent under the steam hammer used—a No. 2 Warrington. A drop hammer was used by the contractor on the lock with the same piling, but it broomed the tops of many piles and bent nearly all that he drove by this method.

The cement used in the abutment was 7,280 barrels of Edison Portland, furnished in 95-pound sacks and tested on the work by the United States. All cement received proved satisfactory and set under all conditions very uniformly. It is to be noted that the abutment concrete was all placed in the winter season.

The concrete used was a 1:3:6, mixed in a 1-yard steam driven Ransome mixer, mounted on a deck flat. Six-yard sand and gravel bins were built over the mixing box with levers to control the amount of sand and gravel flowing to the receiver bin. Sand and gravel were delivered alongside of the mixer in flats and were loaded into the 6-yard bins by a derrick boat equipped with a 1-yard Hayward clam shell bucket. Cement to the amount of 80 tons was stored in a shed built on the mixer, just aft of the sand and gravel bins. An incline, with 25-pound rails, carrying a cement car of 1-barrel capacity, kept the receiver bin supplied with cement, only one man being required for the work; *i. e.*, to load the car in the shed; a small steam engine drew the loaded car to the top of the incline, where it dumped automatically and reversed the engine and returned down the incline to be reloaded.

This arrangement of mixing plant proved very satisfactory and had a working capacity of 21 cubic yards of concrete per hour. The traveling derrick removed the mixed concrete to the forms in a specially designed two-line bottom dump bucket.

The plant used to build the abutment consisted of the following:

1 derrick boat with three drum hoist and swinger.

1 traveling derrick.

1 cement mixer complete on flat.

1 Emerson pump.

1 river pile driver.

1 land pile driver.

1 Warrington steam hammer with false leads.

The necessary picks, shovels, etc.

The necessary lumber, bracing and steel sheet piles.

52,774 bushels of sand were furnished by the Rodgers Sand Co., of Pittsburgh, Pa., in 100-yard flats, at 2.9 cents per bushel, *f. o. b.* at abutment.

158,153 bushels of gravel mixed with sand were furnished by the Rodgers Sand Co., in 100-yard flats, at 1.7 cents per bushel, f. o. b. at abutment.

The following scale of wages prevailed:

Overseer, \$125 per month.

Foremen, \$90 per month and \$3.44 per day.

Enginemmen, \$3 per day.

Firemen, \$2 per day.

Carpenters, \$3.20 per day.

Skilled laborers, \$2.48 per day.

Day laborers (American), \$2 per day.

Day laborers (Italian), \$1.60 per day.

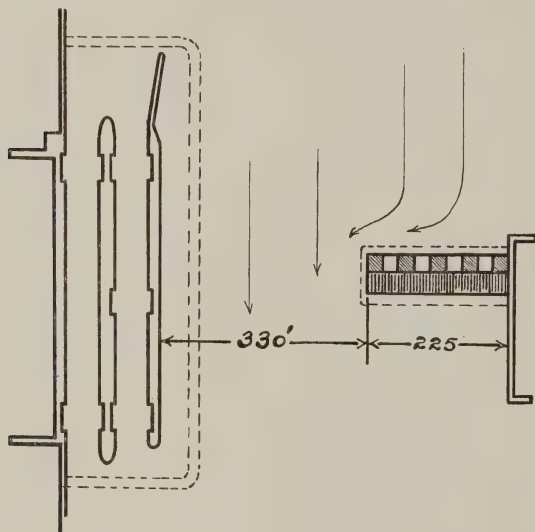


Fig. 7. Stage of operations August 20, 1909. Lock completed and ready for installation of gates, operating machinery, etc. Removal of the cofferdam around lock site commenced, first 225-foot section of dam finished in alternate 25-foot monoliths.

The following figures give a general idea of the quantity and unit cost of some of the items involved in the construction of this abutment:

10,119 cubic yards of material, rock, clay and gravel excavated at \$2.30 per cubic yard.

7,022 cubic yards of concrete placed at \$4.47 per cubic yard.

1,087 steel piles driven at \$7.26 per pile.

849 steel piles pulled at \$7.40 per pile.

114,024 feet B. M. of trench bracing placed at \$19.16 per M.

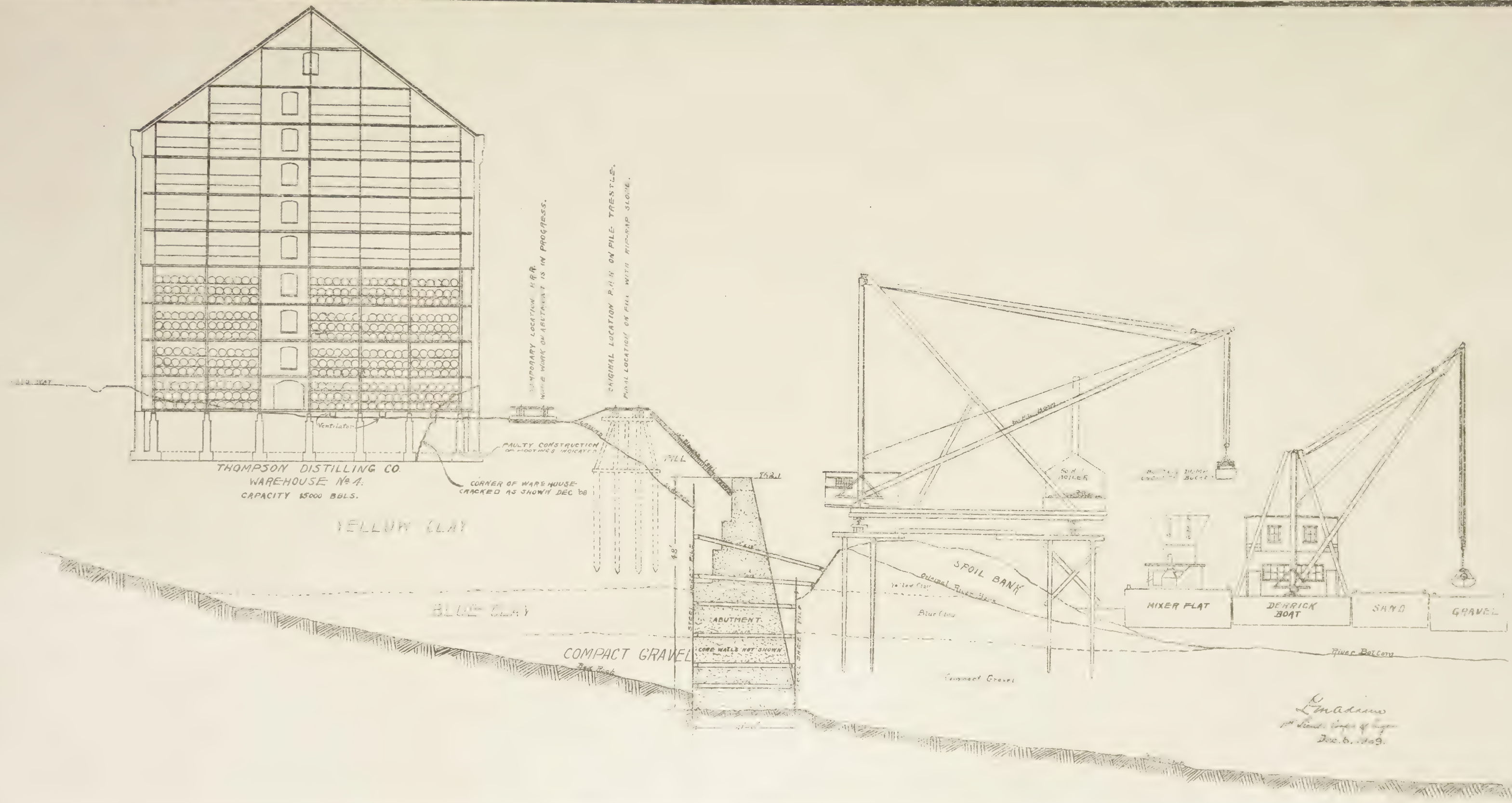
In looking over these unit cost figures it must be remembered that great inconvenience and difficulty attended all construction operations due to local conditions.



SPoil BANK
Original River Bank
Clay
Blue Clay

Connect Gravel





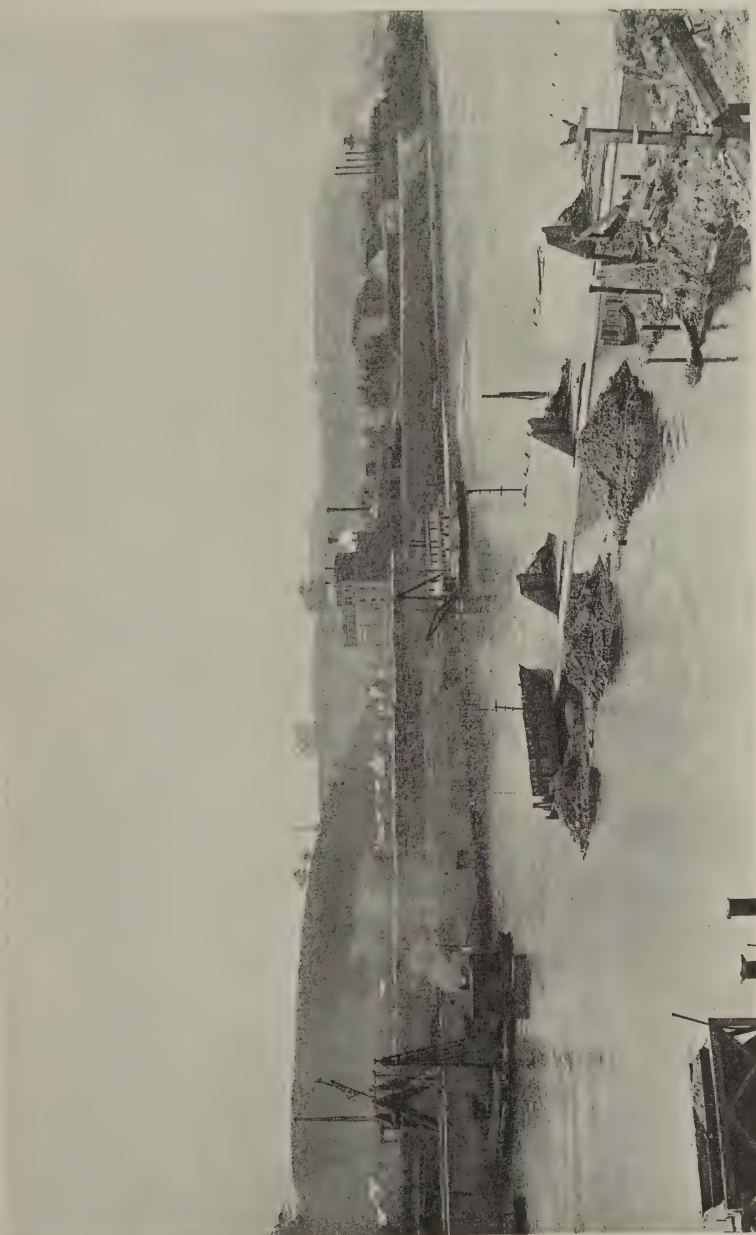


Fig. 8. Near view of incompleted section next to the abutment.

The total cost of the abutment was \$65,504.74, and the original estimate was \$68,250, made by First Lieut. E. N. Johnston, Corps of Engineers, when that officer was engaged upon its design.

The large warehouse previously mentioned, which cracked while the work of constructing the abutment was under way, has since been repaired at the expense of the Pennsylvania Railroad Co., whose line handicapped the Government work.

THE DAM

As the abutment was rapidly nearing completion, the assembling of plant and material to construct the dam was begun during February, 1909, and actual work commenced in April. It is imperative that no interruption to navigation on the Monongahela should occur while construction work is in progress. It is clear that the building of the fixed dam could not progress any faster than progress on the lock would permit; in other words, the river channel could not be shut off until one of the locks was in operation. As the cofferdam for the lock shut off 175 feet of the river next to the right bank, the remaining channel opening across to the abutment in the left bank measured a scant 500 feet. After making provision to leave sufficient channel to carry off any moderate rises in the river, it was decided to build the first part of the dam in one section, 225 feet long, next to the abutment. This plan would leave an opening 275 feet wide for navigation until the lock cofferdam was removed. The 225-foot section of dam would be built in nine monoliths 25 feet long, and each alternate monolith would be built full crest height, or 9 feet above upper miter sill, corresponding to elevation 747.1. Five monoliths were built full crest height, and the other four alternate monoliths in this section of the dam were built up to elevation 737.1, or about ordinary low-water level when Dam No. 4 below has its flashboards up. The object of this construction was to provide a spillway of four 25-foot openings to carry off the discharge of the river when final closure of dam is undertaken. The following method of construction was carried out: Two floating pile drivers were set to work driving the round piles in the dam substructure, and when these were driven, two 6 by 12 inch waling strips were bolted, at water level, to the upstream row of 30-foot round piles; between these waling pieces was driven a solid row of 30-foot Wakefield hardwood sheet piling, extending out from the abutment 225 feet, then turning at right angles and extending downstream 60 feet. A section of apron crib 225 feet

long was then sunk in its permanent position just below the round piling. The row of Wakefield sheet piling was braced across to the stone-filled crib, and a dredge began banking material against the downstream side of the crib and against the outer face of the Wakefield sheet piling. A 10-inch centrifugal steam pump was set up on a grillage supported upon the crib, and the entire enclosure, 225 by 56 feet, was unwatered in a few hours. All round piles were then sawed off at proper elevation, and the row of 4 by 12 inch by 20 foot wooden sheeting, above the crib, was driven in the dry with a land driver supported on skids laid along the crib. The floating con-

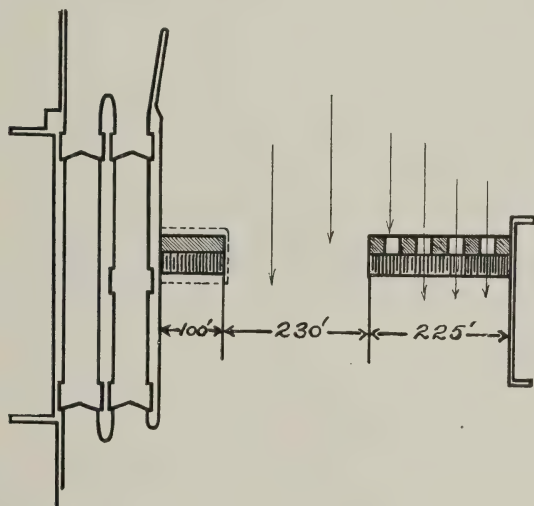


Fig. 9. Stage of operations November 20, 1909. Lock completed and about ready for operation. Cofferdam around lock site removed. Second section of dam 100 feet long finished solid. Cofferdam around first 225-foot section removed; cofferdam around second 100-foot section ready for removal.

crete mixer was then put in operation, and the concrete work brought up as previously described, the crib decking being spiked down in the dry meanwhile.

This 225-foot section of dam was finished, as contemplated, the last week in August, 1909, and as the contractor on the lock was ready to tear out his cofferdam, the plant for building the dam went ahead with the second section—the 100 feet next to the river lock wall. By the time this last 100-foot section was finished, the lock gates, machinery, etc., had been installed, the river lock was ready for operation, and driving of round piles in last closing section of the dam began.

On the final closure of such a dam, the remainder of the construction work is comparatively plain sailing, only a question of working rapidly to avoid numerous floodings.

A few words regarding the design of the dam may be of interest. Loaded coal fleets sometimes break loose during floods, coming down the river with considerable velocity; only a gravity type of dam construction could survive such an impact, and the various types of hollow reinforced concrete structures could not be seriously considered. Bed rock being at too low an elevation to be used as a foundation, it was necessary to plan a substructure that would

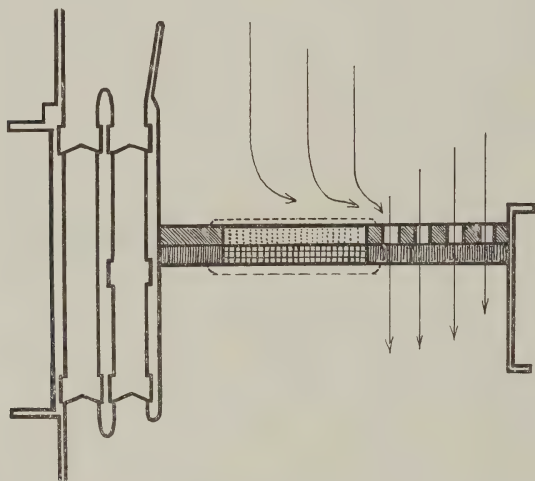


Fig. 10. Stage of operations January 1, 1910. Lock in operation and all navigation passing through it. Final closing off of river channel completed with upper pool 4 feet above lower pool at ordinary river stages. River is discharging entirely through the four 25-foot openings in dam near the abutment. Round piling in last section all driven, crib sunk, Wakefield sheeting driven and coffer banked up.

guard against undermining, and provide a water seal to prevent large leaks starting. The round piling, driven to bed rock, met the first of these conditions, and the closely fitting Wakefield sheeting sealed off the base. Some leakage through the Wakefield sheeting is bound to occur under 12 or 15-foot head, and the precaution was taken to spread a 2-foot layer of permeable material directly beneath the concrete body. This permeable layer will not allow a hydraulic head to form, with its undesirable buoyant effect. The dam was examined by the method of graphical statics under all possible conditions (movable top down or up) and found safe. The

4-inch sheeting just above the crib is not designed to be water-tight, as this would cause a serious head to form beneath the dam. This sheeting is to protect the foundation of the dam from being washed out if the crib should be undermined by back lash.

Previous experience on the Monongahela warranted the assumption that a fall of 12 feet would require a crib width of 30 feet. The crib is of course decked with heavy timber to prevent the boil from washing out the stone filling. Heavy derrick stone is thrown below the crib as an additional precaution against back lash undermining.

The movable top adopted is a series of hinged steel and wood

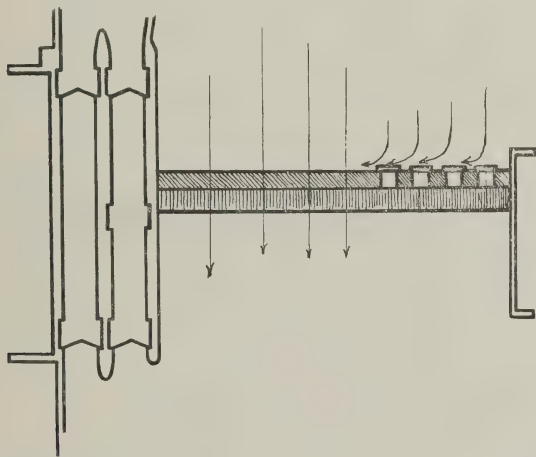


Fig. 11. Probable stage of operations March 15, 1910. Lock in operation and dam completed, excepting the four 25-foot openings near abutment. Each of these openings is covered off with heavy 30-foot timbers, allowing final completion of concrete work in dam.

flashboards, each 12 feet long. They can be adjusted to drop to the lying position automatically when the depth of water passing over them rises to a definite point. As the depth spoken of increases, the center of hydraulic pressure on the flashboard rises correspondingly until equilibrium becomes unstable and the whole board drops, opening a gap in the movable top and giving increased discharge capacity. If the river continues to rise, the flashboards all drop down and out of the way. When low-water conditions again prevail, a maneuvering boat in upper pool can again raise the flashboards to their standing position, causing upper pool to rise 3 feet as before.

To enable the river lock to be used to pass vessels at any stage of work on the dam, it was built with its upper sill at elevation 726.1, the same as its lower sill. This design required that the upper gates be full height. To accomplish this, the full height intermediate gates, river lock, were hung as upper gates, and the permanent short upper gates for river lock were built behind the land wall and left there. Final completion of the dam will allow the river lock to be put out of operation, unwatered, and its upper sill brought up to permanent elevation of 738.1, the same as the upper sill land lock. The short gates will then replace the long ones, and the latter will be hung as intermediate gates.

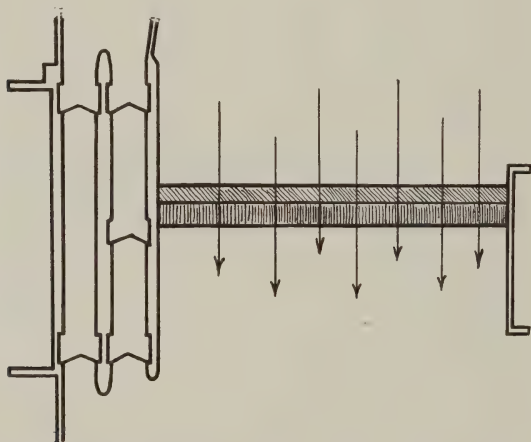


Fig. 12. Probable stage of operations April 15, 1910. Dam completed, river lock out of operation and unwatered; navigation now passing through land lock to allow upper miter sill river lock to be built up from temporary elevation, 726.1, to permanent elevation, 738.1, same as upper sill land lock.

In building the dam the following plant was required:

- 1 1-yard Ransome concrete mixer, steam driven, complete on flat.
- 1 derrick boat, 75-foot boom; to supply mixer with sand and gravel and to handle concrete bucket, forms, etc.
- 1 derrick boat, 45-foot boom; to supply mixer with sand and gravel and to handle concrete bucket, forms, etc.
- 2 floating pile drivers.
- 1 steam dipper dredge complete with two 100-yard dump scows.
- 1 steamboat to act as tender for dredge.
- 2 empty flats.
- 1 land pile driver.
- 1 10-inch centrifugal pump.
- 1 flat fitted with tool house and 50 horse power steam boiler.

RANDOM NOTES ON ENGINEERING IN THE PHILIPPINE ISLANDS*

BY

CAPT. AMOS A. FRIES
Corps of Engineers

Before going to the Philippine Islands in 1901, I had a little of the then American prejudice against the Spaniard, due to the Spanish War. Yet I was far from thinking him altogether bad or devoid of ability.

During a stay of almost two years in the Islands I learned that however corrupt and inefficient some of the governors, military commanders and other high officials might have been, many of the engineers had shown ability of no mean order, and, judging by their works, many must also have been earnest, energetic and honest. Their mistakes, so far as my observation went, were largely in attempting to give every structure too great a permanence. My work was mainly repairing and extending wharves into water 20 feet deep at low tide.

In 1901 there was outside of Manila hardly a wharf in deep enough water to let even the smaller transports alongside to load or unload. Supplies were lightered from vessels anchored from a quarter to 2 or even 3 miles out from shore. This lightering added greatly to the expense of maintaining armies in barracks or in the field, at a time and in places where such maintenance was high at the very best.

The wharf built by the Spanish engineer was usually well located. Likewise, his roads were well laid out, graded and macadamized, and had brick or stone bridges and culverts.

The Spaniard, priest, soldier or civilian, remained near the shore, and hence around every important island there was a fringe of civilization. This fringe varied greatly in width.

Fertility of the soil, nearness of mountains to the shore, size of rivers and hostility of the natives all contributed to limit the width

* Read before Engineers and Architects Association of Southern California, July, 1906.

of the fringe. Where there was no river valley, the fringe would ordinarily be from 5 to 20 miles in width. Naturally the fringe was broken. In many cases the civilized portion was less than the uncivilized.

Like all peoples in all times, the Spaniard's progress stopped where transportation failed. Providing transportation inland in the Philippines was serious business. A moist, hot climate, coupled with a naturally rich soil, made vegetation rank and of exceedingly rapid growth. Beasts of burden were scarce and of poor quality. The carabao, a sort of water buffalo, large and strong but a snail in speed, was, and is yet, the principal work animal. At rare intervals one saw a true Indian water buffalo, a much smaller and livelier animal than the carabao.

Lastly, there were the native ponies, just about as tall as our Shetland pony but less bulky and far speedier. These little animals possess truly wonderful endurance, but are most common in and near cities for carriage and 'bus horses.

While the carabao and the pony were the commonest beasts of burden, the average native owned neither. He depended on his own legs, head, and back, for necessary transportation. Thus he required only a trail—and more than that—the inherited skill of numberless generations enabled him to glide along with his bundle where the trails were simply holes through timber and rank vegetation, and where the sunlight filtered through in small patches, if at all.

Even in our own country, except where very dry, roads are soon covered with undergrowth, unless continually in use. So the Spaniard learned that roads extending far into the country could not be found after one season, and, profiting from experience, built his roads near the cities, and built them well, so they would stand use and invite travel. Otherwise he stuck to the water courses, usually the ocean, where the roads were wide and needed no repairs. Those natives who lived near the shore took to the water naturally, and in handling their boats developed remarkable skill and speed. Their small boats, sharp-prowed and sharp-keeled, fitted with bamboo outriggers to prevent capsizing, were able to outsail any Spanish boats prior to the days of steam. Naturally the bolder ones were pirates, and only when steam made more speed possible could they be quelled.

The two wharves I worked on were well located, and the same was

apparently true of a number of others that I saw more or less casually.

The wharf at Zamboanga, on the Island of Mindanao, the second largest of the group, was built with roughly cut stone walls for about 450 feet, with two openings 22 feet wide about 100 feet apart near the center. The interior was filled in with small rock and earth and the surface macadamized. There was also a wood extension 140 feet in length built on piling with four pile bents spaced about 6 feet apart. The Spaniards had built the wood extension seaward with an upward slope of about 1 in 100.

The harbor was really an open roadstead protected against the prevailing storms by an island about 3 miles away, and also by a long reef extending westwardly from the island.

After studying the situation, it was decided that a wharf level with its surface at the same elevation as the stone part of the wharf would be the most useful and take shorter piling. This, of course, necessitated cutting off to grade the molave piling already in place, because at that time my steam pile driver had not arrived, and I could not budge them with a hand driver I improvised. However, had I known how terribly hard seasoned molave is to saw, I should have waited for the pile driver. I verily believe solid lead piling would have been as easy to cut.

As might be expected, the water around this wharf had shoaled a great deal, because the small openings previously mentioned allowed no currents to speak of for moving the sand away. Yet, under and for about 10 feet each side of the piling the water was deeper by nearly 5 feet than elsewhere.

I had to build the wharf entirely with soldier labor, and although I had about seventy to start in with, I finished with six. The rest had been sent out on urgent field duty. I was chief engineer, superintendent, master carpenter, and when my only steam engineer took dysentery in the early part of the work, I had to run the pile-driver engine two days before I could train another man.

When I began repairing the wharf in 1901, the timber work was practically rotted out, except the piling. This piling had been in place thirteen years. The wood was molave, of which there are two or three varieties. This piling was of the yellowish variety. Molave is the hardest and most durable wood in the Islands.

The teredo is very bad in Philippine waters, and I saw 8 to 10 inch soft wood piling destroyed in three months. Into these molave piling the teredo had penetrated through the sap (about 1½

inches in thickness) and about one-half inch into the heart of the wood. There they had stopped. Why, I do not know for certain, but I judge on account of the hardness of the wood.

Repeated attempts were made to drive 60-penny spikes, both wire and cut, into these piling, but not a single one was successful. Holes were bored for all spikes and all bolts.

In general, the valuable woods of the Philippines are hard and heavy. When green they sink in salt water like iron, and even when seasoned for years will float only a few moments. There are softer and lighter woods, but as a rule they are not very strong or durable. They are used mostly where kept dry and not subject to wear. Although knowing *molave* to resist *teredo* and abrasion, and to be the most durable of Filipino woods, I quickly discovered that I must do my work with other woods, due to the scarcity and cost of *molave*, coupled with the fact that it grows gnarled and with large branches near the base, making it very difficult to get pieces fit for piling of greater length than 30 feet. So valuable is this wood that it has sold in Manila for \$2, gold, per cubic foot. To instance its durability, the tenons on the tops of the piling that had been in place thirteen years were so perfect that every saw-cut was clear and sharp, yet the mortise, and, in fact, almost the whole cap of *pagatpat* was utterly rotted out—and *pagatpat* is an excellent wood, too.

I used for piling a native wood called *yakal*. It resembles our elm, though there is less difference between sap and heart. It is hard and heavy, splits easily and straight, and grows tall and slender in thick woods. When seasoned, it has a light, chocolate-brown color. It was said to resist the *teredo* for five to seven years. There has not yet been time to decide this, and I have not at hand any late information. I used *pagatpat* largely for decking and timbers. *Pagatpat* is very dark, hard, rather brittle and resembles in color our walnut.

Of other woods used there was *lumbayao*, a soft and lighter wood, which was used somewhat for decking. It appeared good and was recommended by natives and Spaniards for use in places not subject to frequent wetting and drying.

Then there is *batitinan*, resembling *yakal* considerably in hardness and color, but even better known than *yakal*. I judge it does not split quite so easily as the latter.

Narra is a hard, light-red colored wood of good quality and

capable, as, in fact, are nearly all Filipino hard woods, of taking a fine polish.

Then there is the native mahogany and ebony, used for walking sticks and fancy articles generally. A little teak is sometimes cut for shipbuilding, etc.

Lastly, but most important to the average native, is the bamboo and the palm. These furnish food, fuel and shelter, and the bamboo is also used in battle for bows, sharp stakes, catapults, etc.

The meat of the cocoanut is used for food, and its husk makes a good fire for cooking.

One of the drawbacks to lumbering in the Philippine Islands is the heaviness of the wood. The valuable varieties can not be floated except by rafting them with bamboo or other inferior varieties of timber, or by loading them on boats or lighters. I lost fifteen good piles by a lighter springing a leak and turning bottom up in 300 feet of water. Fifteen piles here would be considered nothing, but with me it was serious.

Getting the piling out of the forest was slow work, and then I had to tow them 20 miles, and like everything else modern out there, tow vessels were scarce.

Returning to the subject of wharves: there is at Jolo, on the Island of Sulu or Jolo, the usual stone wharf extending out to some 14 feet of water. This is built on a rubble mound. The walls are random rubble, built with the largest stones the Spaniards could handle with little or no machinery. The largest size weighed probably 1,000 pounds. This rubble was laid dry, and so well was the work done that it held together even when undermined for several feet in length and as much as 4 feet crosswise. It is the best piece of random rubble I have ever seen. The interior above low water was filled with smaller stone, mostly coral, though a little was of volcanic origin. This wharf, as I now recall it, was some 350 feet in length and 18 feet wide with a cross having arms about 50 feet long, about 100 feet from the outer end, the wharf terminating with an L, say, 40 feet long. An inscription on the wharf says it was built in four months, and with no modern appliances it was certainly a feat worth commemorating.

The roadway of the wharf was composed of, first, a layer of fine sand, then clay, then small rock, then more sand, and, finally, broken stone and sand, the whole being some 15 inches thick.

They used over the outside of the rubble walls an unusual plaster, made of pure clay, sand, cement and lime. The proportions were

said to be about 1-10 Portland cement, and about 3-10 each of lime, sand and clay. The plaster was really very good, except where exposed to sea water.

This town of Jolo has a romantic history. Long years ago it was a fever-stricken village on the edge of a swamp scourged by frequent raids of the savage Moros, and, to add to its terrors, it was a Spanish penal colony, where there is said to have been in earlier Spanish times always about 1,000 prisoners.

A certain General Arolas, disliked by the reigning powers for his political views, was sent there to die, as this was probably considered an easier and more diplomatic way of getting rid of him than by ordinary assassination. Having nerve and energy and not wanting to die just then, the General went to work to make the place sanitary and habitable. He first built a stone land wall to keep out the savage Moros; then filled in the swamp out to and even beyond low tide; built a stone sea wall and the stone wharf previously described, with a light-house and look-out near its outer end, and then set to work to put up buildings. He laid out a town of about 30 acres inside the walls he had built, erected barracks, dwellings, storehouses, and allowed the Chinaman—the business man of the Philippines—to come in and set up in business. He then piped water to the town from a distance of about a mile, and protected the source of the water supply by a strong stone fort. He paved the streets and made gutters of cement, sand, lime and clay plaster. Then his sentries made all Moros deposit their arms at a point about 100 yards from the gate before any might enter.

In fact, he built a model town, and made almost a health resort of a fever-stricken swamp. If he was not an engineer, he knew how to choose good ones, and I take off my hat to him and to his engineer, nameless though the latter be.

The Spanish stone forts were well built, and though not calculated to resist modern guns, they were thoroughly efficient against the natives. The walls were generally from 12 to 16 feet high with a slight batter. They had portholes for rifles and embrasures for cannon. Where possible they inclosed a water supply or were built so as to protect one. They used the best stone to be found in the locality, but did not go hunting for granite, if an inferior stone would do. For instance, the wall surrounding the old city of Manila was faced with cut stone of a variety exceedingly soft when first quarried. In fact, they chopped it out with a sort of pickaxe. However, after being quarried awhile it becomes about as hard as

good brick. It is much used to-day for a good class of Manila houses and for foundations. It looks almost uncanny to see a native chopping a line in the quarry just as an American laborer chops a line in the street. This stone is apparently very durable in walls, but is utterly worthless for roads or in any place subject to wear.

The interiors of heavy walls were filled with concrete apparently made with ordinary lime mortar.

Some forts, like the city wall of Manila, were surrounded by a wide, deep moat filled with water, with bridge entrances protected by special works. The city wall of Manila is an excellent type of the fort so thoroughly developed by Cormontaigne and other French engineers in the seventeenth and eighteenth centuries.

This wall around old Manila is an exceedingly interesting study. There are vast numbers of rooms about 18 by 55 feet used as store-rooms, prisons, magazines, etc. One of my first duties in Manila was to determine just how much masonry there was in that part of the wall facing the Pasig River. Naturally, I measured every room and crawled into every hole big enough to admit a man.

The first fort built at Manila by the Spaniards was called Fort Santiago and was completed, I believe, about 1589. It was relatively small as compared with the later city wall, which was completed just about two centuries later. In this wall, wherever the stone was exposed to considerable wear, as from the wheels of guns or on stairways, it was faced with granite or other hard stone.

On account, largely, of earthquakes the Philippine houses are usually only one and two stories,* but with occasional important Government or church buildings of three and four stories having towers of still greater height. The larger buildings have very massive walls, and even then are occasionally severely injured by earthquakes.

The better class of frame houses have stone walls for their first stories, but are braced by heavy posts set firmly into the ground and extending through to the roof. These posts are at the corners, though in some of the larger houses there are additional ones along the sides and interiorly. They are then fastened together at the top with heavy cross beams. Molave wood, previously mentioned as the most durable of all Filipino woods, is in great demand for the bottoms of these posts. A foot or two above the surface of the ground a joint, lap or mortise, is made and an inferior wood extends up through the building.

Among harbors the Spaniards had improved Manila Bay and

the harbors at Cebu and Iloilo. The latter-named cities are some 250 miles south of Manila on islands of the same name.

The most work was done at Manila, where river improvement, coupled with an outer harbor protected by a breakwater, forms a close analogy to the harbor of San Pedro.

The Americans have enlarged and modernized the Manila harbor scheme. Its main difference from San Pedro lies in the fact that the river entrance is not protected by the breakwater, and in just so much is less perfect than the San Pedro scheme.

The breakwater is a rubble mound capped with large cubical concrete blocks. The sides of the cubes were some 4 or 5 feet. The Spaniards had large numbers of these blocks made and stored prior to 1898. A bulkhead was driven parallel to the shore protected by the breakwater and some distance out. The bottom outside the bulkhead is being dredged to 30 feet and the material is deposited behind the bulkhead. It is then planned to build nine or ten slips out from the bulkhead, utilizing the made land for streets, railroads, storehouses, etc. This work is the largest undertaking in the Philippine Islands and will cost some \$5,000,000 when completed.

Boats drawing 18 feet can go up the Pasig River a mile or more, but there is no chance to develop a great inner harbor, as at San Pedro. The breakwater is therefore a greater necessity at Manila than at the latter place.

I have spoken mostly of Spanish works begun or completed, because the American works or methods are not so very different from those in the United States.

Recently electric cars have been installed in Manila and a huge sewerage system begun.

The work of the Americans has been almost wholly to increase transportation facilities. Many roads were built, some good, some indifferent, some bad. Often they were built for urgent military reasons, and consequently were not made permanent, both time and money lacking. The best and most widely advertised road is that to the summer resort at Baguio, some 50 miles from the sea, at an elevation of about 5,000 feet. This road was built by the civil government at an average cost of over \$10,000 per mile. It is better than the military roads, but that is not to be wondered at, since the military authorities had from nothing a mile to possibly \$1,000 per mile in one or two cases.

A good road was built in the Province of Batangas, just south of

Manila, and two very good roads in Mindanao, the latter being constructed almost wholly by soldier labor.

Many a soldier has cursed the day he enlisted, because instead of fighting he found himself with pick, shovel and axe building roads under a torrid sun, through jungles and swamps, across rivers and mountains, with mother earth or boughs of trees for a bed and hard-tack and bacon for food—and the latter not always plentiful.

One of these military roads in Mindanao was 21 miles long, extending from the sea to the crest of a bluff 3,000 feet above the sea, overlooking a beautiful fresh-water lake 800 feet below. There were not many reversals of grade, the total climb being 3,500 feet to reach an elevation of 3,000 feet. Twelve per cent grades were occasionally necessary. The road was partly laid out before the Engineers arrived on the scene, and of course had some bad places that might have been avoided, but on the whole it was a good road. The soil after about 18 inches had been removed was almost ideal for road making. It was coarse and granular and packed well, so that when wet it never formed mud. It also remained well packed during long, dry spells. The torrential rains on steep grades caused the roads to cut up some, notwithstanding the liberal use of timber "*thank-you-ma'ams*" at close intervals on grades at all steep. The monotony of work on this road was varied by night attacks by savage Moros, by terrific rain and wind storms and by violent earthquakes. Dysentery lurked in every pool, while malaria buzzed on the wing night and day, and, to make things still livelier, the deadly Asiatic cholera swept the country. Referring to earthquakes, one was so severe that tents even were thrown down. Many amusing incidents occurred at camp during and immediately following this 'quake. In one instance a convalescent soldier whose mind had been affected proceeded to the open space just in front of camp, and as each succeeding 'quake came (there were 120 lesser shocks during the twenty-four hours following the main shock) the soldier would kneel solemnly and, raising his right hand, with his eyes cast Heavenward, would say, "Steady, Lord; easy now, Lord; easy, easy."

As for rains, in one storm 12 inches fell in thirty-six hours. In such a storm the little shelter tents carried by the soldiers were only a shade better than the stormy sky as a protection against the water. But better transportation for supplies needed by a small army in the field in a hostile country made the road a military necessity.

Realizing the absolute necessity of better inland transportation in the larger islands, the Government is just now completing arrangements for the building of several hundred miles of railroad, and in order to induce capital to put up the money the United States guarantees 4½ per cent for thirty years on the bonds with which the roads are to be built.

Thus our endeavors, like those of the Spaniards before us, are to increase transportation facilities. The study of means for making transportation easier is the work most of us, in one way or another, are engaged in; for the easier is transportation, the greater is prosperity.

How much Los Angeles owes to her railroads, both steam and electric, few people realize. But to continue her growth she must have a good harbor such as San Pedro now gives every promise of becoming. To realize how vital a harbor is to a city one must recall that no city to-day has reached first rank without one, just as no city has become very great without railroads.

Musing a little, one is startled by the thought of how closely transportation and civilization go hand in hand. Where there is the best transportation, *there* is the highest civilization, and where there is practically no transportation but man's back, there is savagery and barbarism.

Then here's to the man who hustles transportation, be he engineer who builds roads, bridges, harbors, or architect who plans offices, mills, storehouses, or be he "The man behind the gun—the man with the mon."

Prizes for Contributions

An offer has been received from two subscribers to give \$10 each per year for five years to form a nucleus for one or more prizes for the best contributions to the MEMOIRS each year during that period. Certain suggestions have been made as to the allowable competitors and as to the character of the contributions, but nothing has yet been fixed in regard thereto. The editors will be glad to hear from others who desire to subscribe to this prize fund and to receive suggestions as to the rules that shall obtain in awarding the same. The sole object of the PROFESSIONAL MEMOIRS is to increase the efficiency of the service it represents, and to that end suggestions, criticisms, contributions and subscriptions are cordially welcomed.

THE DETROIT RIVER TUNNEL

BY

LIEUT. STUART C. GODFREY

Corps of Engineers

The twin tubes of concrete that are being built by the Michigan Central Railroad Company underneath the Detroit River will form, when completed, a much-needed link in the great trunk lines that pass through Detroit. At present all through east and west bound trains are ferried across the river, about half a mile wide at this point, by powerful transfer steamers, a process which, with the attendant switching and recoupling, occupies from thirty to forty minutes. The electric locomotives which will handle the traffic through the tunnel will clip a good half hour from this time. As freight trains are by the present system delayed from three to seven hours, and even longer during the ice-bound months, the gain in time for freight traffic will be a matter of hours, no small consideration in the case of perishable goods.

The problem of overcoming this obstacle to traffic is an old one. The earlier plans contemplated the construction of a bridge across the river, but the vessel interests, fearing any obstruction to navigation on the Great Lakes, were powerful enough to prevent any legislation along such lines. When, largely through the efforts of Mr. H. B. Ledyard, at that time president of the Michigan Central Railroad, the construction of a tunnel was decided on by the board of directors, a company was organized under the laws of Michigan and of Canada, known as the Detroit River Tunnel Company, which was charged with the construction of the tunnel. The plans for the project were intrusted to an advisory board of engineers, comprising Mr. W. J. Wilgus, Mr. H. A. Carson and Mr. W. S. Kinnear.

The preliminaries required no little time for their settlement before the actual construction could be begun. What at first appeared to be a strong opposition from the Lake Carriers' Association had to be overcome. A permit had to be secured from the War Department to undertake the project, and assurance given that its con-

struction would not constitute a menace to navigation. Borings were made every 100 feet along both sides of the site of the tunnel; four test pits were sunk, one at each bank of the river, and one somewhat farther inland on each side, and the samples of blue clay taken therefrom carefully studied. Elaborate plans were drawn and redrawn, and it was not until the summer of 1906 that the plans were finally decided upon, and the contract awarded to Butler Bros.-Hoff Company, of New York.

The most novel and interesting feature of the tunnel is the means adopted of constructing the river section. At this point the river is from 20 to 48 feet deep. Local conditions determine the most favorable locations for the terminals of the tunnel. Hence, to have tunnelled through the rock and clay under the bed of the river by the ordinary shield method would have necessitated unduly steep grades. It was desirable to raise the tube as close to the bed of the river as possible; every foot upward meant an easier grade for the approaches. This led to the so-called "trench method" of solving the problem; *i. e.*, by dredging a trench for the tubes to rest in, lowering into place concrete forms, and depositing concrete around these forms, leaving the tube to be finished from the inside. Estimates were called for upon several plans based on this general idea; the contractors were also given the option of estimating on the more familiar shield method, which would have necessitated first placing a blanket over the present bed of the river. In the method finally adopted, the river section was to be made by dredging a trench, laying a foundation, sinking sections of twin steel tubes, depositing concrete around these tubes to stiffen and support them and, finally, constructing the real tubes of concrete inside the pumped-out steel shells, which thus were to serve not only as concrete forms, but also as waterproofing for the completed tunnel.

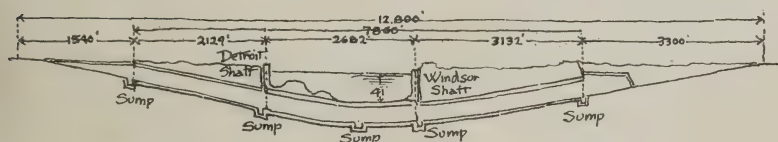
This method is practically unique. A similar idea was applied by Mr. Carson on a small scale in laying some water and sewerage pipes in the outer harbor at Boston; but its application on any such vast scale as the present is quite unprecedented. Besides its great saving in the lift of traffic, the method adopted meant a large saving in first cost, and in rapidity of construction. Its fulfilment has presented many novel and difficult engineering problems, but these have all been successfully met, and the soundness of the new method amply demonstrated. The staff of engineers in charge of construction has included Mr. W. S. Kinnear, chief engineer; Mr. B. Doug-

las, tunnel engineer; Mr. J. C. Mock, electrical engineer; and Mr. A. C. Everham, terminal engineer.

Starting from Fifteenth street in Detroit, the tunnel descends a 2-per-cent grade, following the present line of the Michigan Central tracks. At the end of an open cut 1,540 feet long is the portal of the land tunnel, 2,129 feet in length. Adjoining this is the river section, 2,682 feet long, the roof of which is 41.75 feet below the surface of the water. Thence the tracks emerge into the Windsor approach, 3,132 feet of tunnel and 3,300 feet of open cut, rising at a



ROUTE OF TUNNEL.



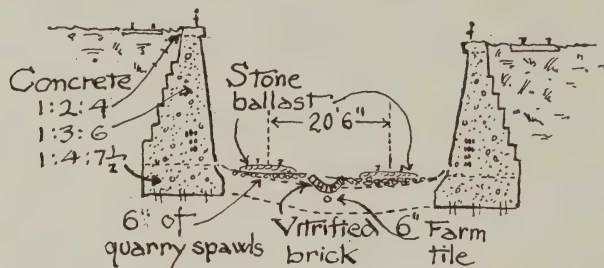
PROFILE OF TUNNEL.

grade of 1.5 per cent. This grade is made less steep than that on the Detroit side, because the east-bound freight traffic is heavier than the west bound, many of the cars headed westward being "empties." The total length of the tunnel is thus about $2\frac{1}{2}$ miles.

The approaches apparently presented no especially novel engineering problems. There were serious difficulties to be overcome, however. The borings had indicated a fairly stiff blue clay throughout the course of the tunnel, apparently presenting no unusual difficulties. But this soil proved treacherous and hard to deal with, yielding to pressure and "flowing" to an unforeseen extent. On

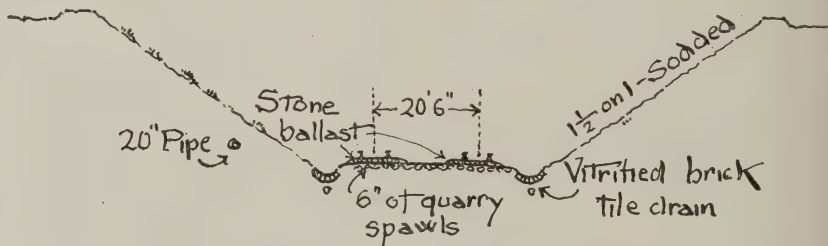
the Detroit side the route of the tunnel lay in a restricted narrow way, passing under several city streets, and closely bordered by large buildings. Four of the eight tracks were removed, and the two through passenger tracks replaced by a single track elevated on a pile trestle. Heavy shoring on both sides of the cut protected the adjacent tracks and the foundations of neighboring buildings.

The open cuts were excavated mainly by steam shovels. At the



DETROIT APPROACH-OPEN CUT.

Detroit end the cut has a maximum depth of 25 feet, and is 36.5 feet in width at the portal. It is confined on both sides for most of its length by gravity-section retaining walls, with an inverted-arch concrete bottom. The walls have a top width of 2 feet 9 inches, which is increased by offsets to a maximum bottom width of 10 feet

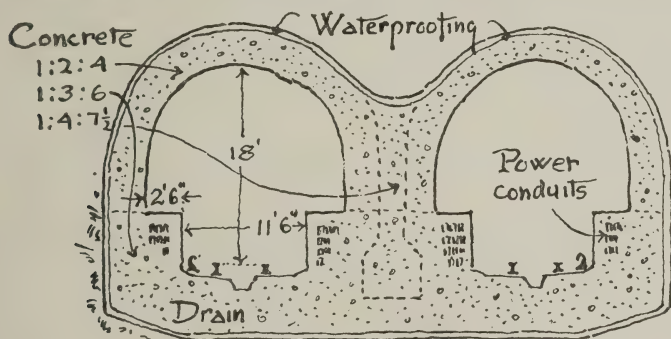


WINDSOR APPROACH-OPEN CUT.

6 inches. These walls were laid in sections 50 feet long, separated by tarred paper. The Windsor cut has a maximum depth of 28 feet; as it is in a much less confined space than the western cut, the retaining walls are dispensed with except for a length of 250 feet adjoining the portal, and the cut built with sodded banks sloping at an angle of 1 on $1\frac{1}{2}$. Some unimportant slips have occurred at these walls. The concrete portals are carefully finished and designed to present an effective appearance.

About 500 feet of the tunnel adjoining the Detroit portal, and a

similar section on the Windsor side, were built by the "cut and cover" method, the open cut being continued beyond the portal, the concrete tubes built in place, and the cut then refilled to surface level. The remainder of the approaches were tunnelled. The first step in this work consisted in sinking shafts near the river's edge on both sides. These shafts were to be eventually lined with concrete and serve as permanent ventilating and access shafts. The interior of the two tubes is of circular cross-section, the circular arc being broken by two benches, which afford a footpath on either side the tracks, and inclose the ducts for power, signal, telephone and telegraph wires. The central wall averages 4 feet thick, and is connected by cross passages every 200 feet. As it seemed impracticable to drive the large twin approach tunnels simultaneously by the



DETROIT APPROACH - CROSS SECTION.

shield method, it was decided to first run a central drift sufficiently large to allow for the construction of the wall separating the two tubes. This massive concrete core would then serve as a guide and springing line for the arches of the tunnel on either side of it.

In accordance with this plan, a drift 14 feet wide and 10.5 feet high was started from the Detroit and Windsor shafts, and from other auxiliary shafts sunk between these shafts and the portals. The height of this heading was then increased to 25 feet by another drift driven just above the first. These drifts were heavily timbered, and on the Detroit side no great difficulty was encountered from the earth pressure. On the Windsor side, however, the clay soil, at the greater depths, was so inclined to yield under the great pressure brought to bear upon it that it was found advisable to use a specially constructed shield 12 feet wide, 16 feet high, with a heavy cutting edge 2 feet 3 inches deep. This shield was operated

by thirteen 8-inch hydraulic jacks, and fitted with two working platforms. As the drift was extended, the walls were braced and cross-braced with heavy timbering, and the arched roof lined with short 30-inch sections, fitted to form an arch ring. In this timbered drift was built up the center wall of concrete. The timbering and the complicated cross section of the wall required great care in the seven distinct operations of laying the concrete.

The construction of the core wall prepared the way for the boring of the tubes on either side. For this purpose shields of special design were necessary, somewhat more than a half cylinder in form, with a generally vertical face fitted with shoes to guide on the completed central wall, and its cutting edge confined to the circumference. Four such shields were constructed, 27 feet in diameter, heavily reenforced to withstand the enormous pressure of the clay. Twenty-one 8-inch hydraulic jacks drove these shields ahead, and behind each shield, working on three different levels, labored a group of from thirty to forty miners, muckers and helpers, gouging the clay from the exposed faces with heavy draw-knives, and rapidly loading the conveyors which travelled on double tracks to and from the shafts.

As the shield advanced, the excavation behind it was immediately lined with continuous rings, made up of 4-foot segments of beech and maple, cut so as to form the voussoirs of an arch, with its haunches resting on the completed center wall. This lining of timber rings was finished with a 2-inch sheathing of beech, forming a smooth surface for the application of the waterproofing. The latter consisted of alternate layers of felt and coal-tar pitch, from three to ten layers being used according to the calculated water pressure. The pitch was applied at a temperature of not less than 250° F., and every precaution was taken that the completed interior of the tube should be permanently free from moisture and discoloration.

The concrete construction closely followed the waterproofing; first the bottom or invert was laid in sections 4 feet long; then the walls were carried up to the springing line of the arch, 12 feet of the wall being laid at a time; finally, the arch itself was sprung in 12-foot sections, keyed to the walls on each side. The forms were hinged at the top and carried on a traveller so that they might be readily lowered and successively moved ahead without disturbing the other forms in place.

✓ In the easterly approach tunnels operations with the side shields were carried on under from 8 to 12 pounds of air pressure. A

heavy concrete bulkhead provided with air-locks gave access to the section under pressure. Two material air-locks, 6.5 feet in diameter and 26 feet long, provided for the passage of cars and material, while a 4 by 4 foot lock permitted laborers to enter and leave the high-pressure chamber slowly and safely. In the completely-equipped laboratory of the tunnel company samples of air from the heading were constantly tested to insure its purity. A hospital was equipped to take efficient care of any cases of the "bends" that might occur. Little trouble was encountered on this score, however. Three separate power plants and 9 air compressors, of the Ingersoll-Rand, Sullivan, and Ingersoll-Sargent type, furnished at low pressure air for the headings, and at high pressure the air used to drive various engines and tools. Two sawmills handled the large quantities of timber involved in the construction. The sand and gravel used in the concrete were dredged from the St. Clair River, about 60 miles above Detroit, and delivered in scows at an unloading plant on the Detroit side.

Simultaneously with the work on the approaches the more unfamiliar problems that the river section presented were being met. The dredging of the trench was commenced in September, 1906, on the American side, as required by the Government, in order that the experience gained in laying the first sections might facilitate more rapid progress across the deeper Canadian channel where most of the traffic occurred. A dipper-dredge made rapid progress on the trench for awhile, but the largest spuds that could be used proved inadequate for the deeper dredging and snapped off when the dipper was making a heavy cut. A clam-shell dredge with a 3-yard bucket was utilized for most of the dredging below 45 feet. This subcontract was handled by The Dunbar-Sullivan Dredging Co., of Buffalo.

When excavated to a depth of 72 feet, the trench was ready to receive the foundation for the tubes. The latter consisted of a heavy steel grillage embedded in concrete, one section being laid at each joint of the tubes so as to support the end of both tubes. The grillage was built up of 12-inch I-beams and channels, heavily braced and fastened in place with four short 10 by 10 inch piles, while the concrete was deposited beneath and around it from the scow above.

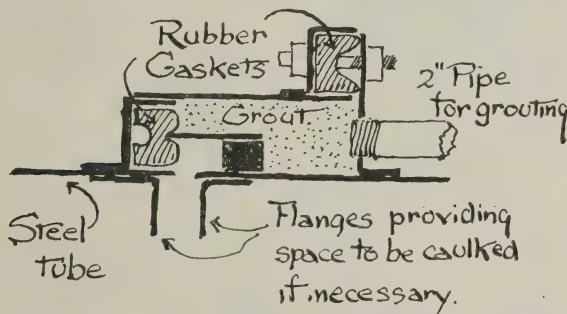
Meanwhile at the Great Lakes Engineering Works at St. Clair, 50 miles up the river, the tubes themselves were being constructed in huge sections 262 feet long. Railway bridge steel, of an ultimate

strength of from 55,000 to 65,000 pounds per square inch, was used in the construction of the tubes, which were of three-eighth-inch plate, and 23 feet 4 inches in diameter. Encasing the twin tubes at intervals of 12 feet were steel diaphragms of one-fourth-inch plate, reinforced with flange angles at their outer edges. The tubes were also braced on the inside midway between each diaphragm by temporary stiffening angles, to which were attached 1-inch radial rods. Plank sheathing, from 3 to 6 inches thick, was fastened to the sides of the diaphragms to form pockets for the concrete, and the ends of the tubes temporarily closed with heavy water-tight bulkheads. The huge hulls thus formed, some 600 tons in weight, were launched sideways and towed downstream to the site of the tunnel.

The first section was sunk on October 1, 1907, and its successful outcome was a matter of no little concern. The tubes were held in place by cables, which led to the drums of hoisting engines on shore. At the shore end of each tube rose a 24-inch manhole, with pipes and valves. Two tall steel columns, painted with red and white checkered marks, served as leveling rods by which the depth of sinkage might subsequently be determined. Four steel cylindrical tanks, 10 by 60 feet, were fastened with heavy straps above the tubes, to provide the necessary buoyancy for the final sinking and adjusting of the tubes. At the bottom of each bulkhead, lying under water, was a 14-inch valve, operated by a hand wheel from a platform above, while corresponding outlet valves provided for the escape of the air within the tubes. When all was ready, a whistle gave the signal for the simultaneous opening of the valves. The tubes sank very slowly, the shore end sinking somewhat faster on account of its additional weight. Transverse bulkheads had been constructed across the upper part of each tube to form air-pockets and prevent uneven settling, but, in spite of this precaution, leaks allowed the air to escape, and the accumulation of water at one end caused a sudden plunge, sending the other end high out of water. The buoyancy tanks, however, eventually brought the structure to an even keel, with its upper surface just a-wash. The process of sinking occupied one hour and forty-four minutes—corresponding to a minute to the time calculated by the engineers. The lowering of the tanks to their final position with the aid of the buoyancy tanks was under perfect control, and with the assistance of divers, who inserted shim plates where necessary, the tubes were accurately adjusted on the foundation prepared for them. The buoyancy tanks were then removed and floated up to be used again.

The problem of obtaining water-tight joints between the sections was an important one. To this end the tubes were made telescopic, a sleeve on one tube receiving the end of the other tube. Each new section sunk was fitted at its extremity with two pilot pins with taper points. On the section already sunk were two corresponding sockets, through which cables from the pilot pins passed, and hence to winches. The tension on these cables guided the latter section to its exact seat, and as the precaution had been taken of assembling and fitting the corresponding joints in the construction yard, a perfect joint was assured. The tubes were bolted together by divers. The joints in the sleeve were closed by heavy rubber gaskets, leaving an annular space 3 by 18 inches to be filled with cement grout. This grouting was inserted from the inside of the tubes.

The next step consisted in laying the concrete around the tubes.

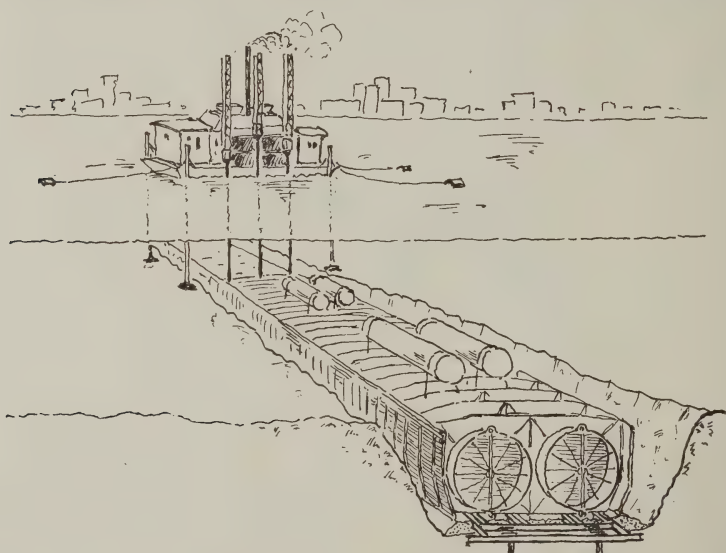


JOINT BETWEEN SECTIONS

A specially large and well-equipped scow was constructed for this work, 36 by 154 feet in size, and fitted with heavy spuds. Above the two-story superstructure were screening-hoppers for the gravel used in the concrete, which was mixed in three separate concrete plants. In depositing the concrete, the scow was fastened by its spuds across the tubes, and the three long delivery tubes or tremies lowered, one on each side and one between the twin tubes. The concrete was delivered from the mixing plants to hoppers, which were elevated so as to discharge their material into the heads of the tremies, whence it was deposited wherever required at the bottom of the trench, and in the pockets formed by the diaphragms and the side sheathing. Rapid progress was made in depositing the concrete, two 12-foot pockets being sometimes filled in a day. Remarkably good results have been obtained from the tests of the concrete thus deposited in the wet, some specimens showing a compressive strength as high as 4,000 pounds to the square inch. This is attrib-

uted to the great pressure brought to bear by the water on the surface of the concrete as deposited, and to the absence of air-holes. When the tubes had thus been encased in a monolithic mass of concrete, 56 feet wide and 32 feet deep, the remainder of the trench was backfilled with the material previously taken out, and brought to the level of the bed of the river, the filling being protected in places by a 2-foot layer of riprap.

The problem of uniting the Detroit approach tunnel and the river section was solved by constructing a cofferdam and connecting the two sections under its shelter. From the Detroit shaft near the

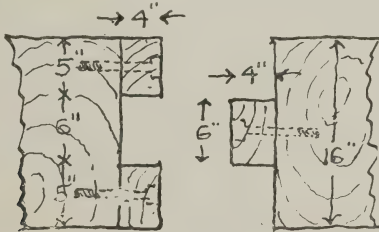


CONCRETE SCOW AT WORK.

shore a drift had been driven toward the river, and an apron of concrete laid to receive the end of the first section of the tubes. The dredge engaged in excavating the trench for the tubes had started a small leak through the walls of the drift, which resulted, finally, in the flooding of the shaft and heading. This accident, however, did not interfere with the method decided upon of connecting the sections. A timber crib was first assembled over the inner end of the river tubes, 84 feet long by 23 feet wide, with heavy walls of 6 by 12 inch timber. This crib was lowered in place so as to rest directly on the concrete covering, with its longer axis perpendicular to the axis of the tubes. The two central pockets of the crib were directly over the tubes, while another pocket extended beyond on

each side. On either side of these end pockets a row of heavy sheeting was driven of 16 by 16 inch timbers, in 50 to 80 foot lengths. Tongued and grooved joints between these timbers were secured by bolting splines and tongues to the adjacent faces. Driven to a depth of from 12 to 16 feet in the stiff, blue clay, these timbers formed secure and tight sides for the concrete filling that was deposited in them up to the top. In the two middle pockets concrete was then placed so as to form a retaining wall with a top width of 6.5 feet and its bottom width the full width of the crib, while the remainder of the pocket was filled with a clay puddling. In order to connect the ends of the crib with the solid earth of the banks, two wing walls of sheet piling were driven, on a line inclined from the axis of the crib. Each wall consisted of two rows of 8 by 16 inch piling of from 30 to 60 foot lengths, driven to a depth of from 12 to 18 feet.

The total length of the dam was 228 feet. The space unwatered

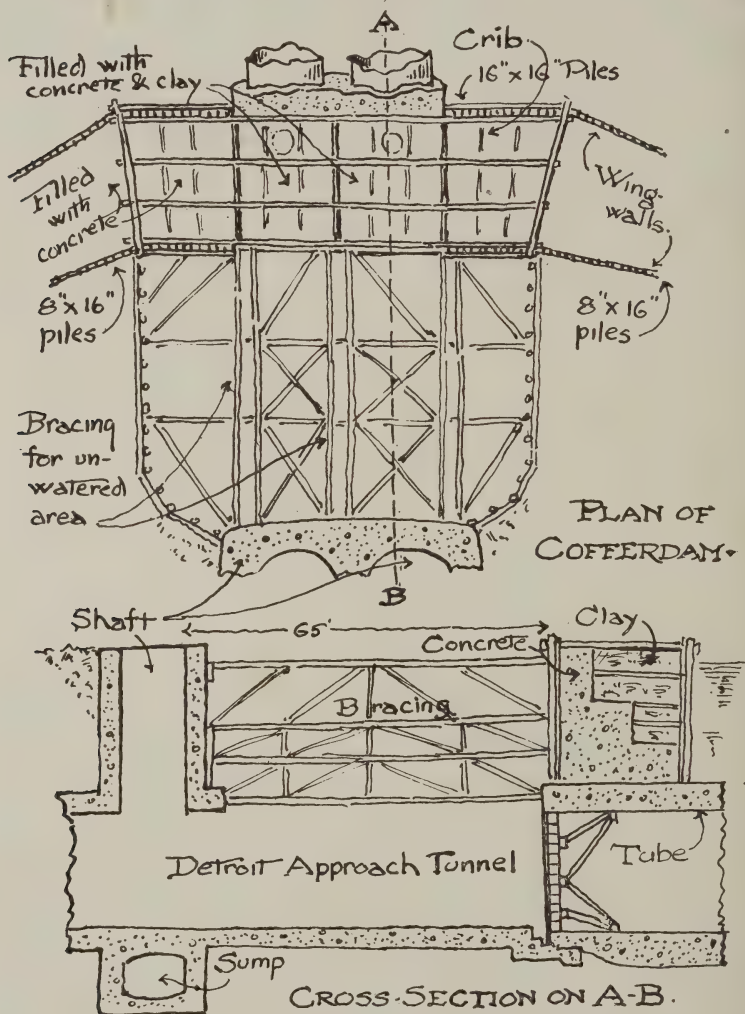


Tongued and grooved joint.

measured 65 feet on the line of the tunnel, 135 feet in a perpendicular direction, and 54 feet below water level, which gives the cofferdam the distinction of being the deepest ever constructed. As this area was unwatered horizontal courses of heavy timbering were laid between the dam and the exposed concrete shaft opposite, not so much to strengthen the dam as to protect the shaft from the heavy pressure of the soil on its other side. An 8-inch centrifugal pump was used in unwatering this area. Practically no leaks were developed. The continuous wall on the river side proved remarkably tight, and what little water came in gained access from the land side, the top layer of the bank being made up of an old fill. The uncovered ends of the river tubes previously sunk were found to occupy the exact position as calculated. Working from these tubes toward the shaft, with a concrete plant located near the latter and delivering material by gravity to the forms at the foot of the cofferdam, the 60 feet of tube connecting the land and river sections was

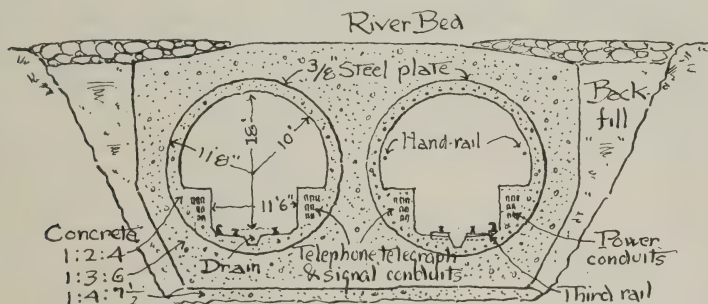
rapidly constructed in 12-foot lengths. The unwatered area was afterwards carefully backfilled, much of the timber being reclaimed, but the concrete being left in place.

With the connection thus made, the work on the interior of the



tubes could be carried to completion. The first tube had been already pumped out and entered through the manhole, but no concreting was done inside until access was gained through the land section. The other sections were successively pumped out, the bulkheads still protecting their forward ends. Inside the steel water-

proofing were then constructed the real tubes of concrete, 20 inches thick. Their cross section is similar to that of the approach tunnel, the two side benches with vertical walls allowing just room enough between for the maximum car clearance. The floor is of concrete, flat, with the sleepers of yellow pine resting directly in recesses in the concrete, to which they are fastened by dowels. Every fifth block is of extra length on the outside, in order to support the third-rail conductor, a 70-pound rail of the under-running type. An experimental section of this type of track, 100 feet in length, was laid near the city, on the Michigan Central lines, and has given good results. The total vertical clearance is 18 feet. The concrete used



RIVER TUBE - CROSS SECTION.

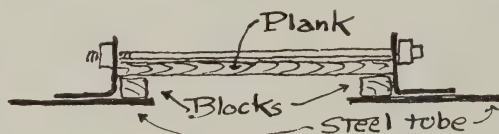
in this inner tube is of the proportions 1 : 2 : 4, and is reinforced longitudinally by 1-inch round steel rods spaced 18 inches apart. The concrete forms and methods of depositing were similar to those used in concreting the approach tubes.

The river section was thus carried rapidly forward, its problems, novel as they were, really giving less trouble than those of the land section. Each successive section of the tubes was laid with more ease and assurance. Since being laid, settlement has occurred to a slight extent, but has now almost entirely ceased. This has been anticipated, however, and in case of continuance plans are in readiness for the construction of supports from the inside of the tubes, where necessary.

The maximum and minimum stresses per square inch on the lining of the tubes have been calculated to be 268 and 58 pounds at the top of the lining, and 293 and 91 pounds at the bottom, a range well within reasonable limits.

Conditions simplified the problem of joining land and river sections on the Canadian side. The original shaft near the Windsor bank was a small one. In enlarging the shaft to working dimen-

sions the bracing employed proved inadequate against the heavy pressure of the treacherous soil, and the lower part of the shaft caved in, filling the greater part of the shaft. No one was injured, as ample warning was given of the disaster. It was decided to abandon this shaft, and to sink another farther from the bank. From this shaft the tunnel was carried toward the river to the point of junction, some 40 feet farther inland than originally contemplated, for the river work was further advanced than that on land. The trench for the river tubes was then dredged to this same point. The eleventh and last section of the tube, a short length of 63 feet, was lowered on September 14, 1909. A clearance of about 20 inches was left between the sections to be joined. These adjoining extremities were fitted with flanges bored to receive bolts. Divers closed the interval between these flanges with short lengths of tight-fitting plank, secured in place by bolts. The concrete was then deposited about this temporary joint, and from the inside of



Connecting joint at finish.

the tubes the wooden collar will be eventually replaced by one of steel. The end of the land section was purposely flooded before the junction was made, in order that any possible damage from a sudden and unexpected flood might be avoided.

Efficient drainage is provided for the tunnel by means of the central drains, emptying into five sumps, one near the central part of the tunnel, one at each shaft, and one at each portal. At these points the excavation is carried some 10 feet deeper, the sumps constructed of concrete, and motor-driven pumps installed to pump out the water that drains into them.

The initial equipment for handling the traffic through the tunnel will consist of six 100-ton direct-current locomotives, each supplied with four 280 horse power motors. Power for operating the system will be purchased from the Detroit Edison Company, and will be delivered at a substation now being erected near the Detroit shaft. There two 1,000-kilowatt synchronous motor-generators are being installed for supplying a direct current to the third-rail. A storage battery will also be installed, to carry the fluctuations in the load, and can if necessary operate the entire plant for half an hour.

The electric lighting and pumping equipment is very complete. The yard and approaches will be illuminated by arc lights and the tunnel by incandescent lamps, spaced 20 feet apart, and so wired that half the lamps in each tunnel will burn should either circuit be broken. The motor for driving the pumps will operate directly at 4,400 volts, will be controlled from the substation, where also will be devices indicating the amount of water in each sump.

There have been no very serious accidents during the construction of the tunnel. Two workmen were suffocated in a fire which broke out in a heading, and two or three others have lost their lives; but there has been no such death toll as similar tunnels driven under water have demanded. The unique method pursued of sinking and lining the river tubes has proven eminently successful, and its adoption is already being considered in several similar contemplated projects. The total cost, including the electric equipment, will be about \$8,000,000. The work is being rapidly pushed to completion, and by the first of April, 1910, the first train of cars will probably have sped silently and smokelessly under the Detroit River.

Creation of a Brigade of Communication Troops in the Austrian Army

The service of the lines of communication becoming more and more important on account of the progress of science, it has become necessary to concentrate it all in the hands of a single management. Therefore, the Austrian Minister of War has just created a brigade of communication troops, which is made up of a regiment of railway and telegraph sappers, of the aeronautic and automobile organizations and to it is attached those taking the course in telegraphy for the infantry and cavalry.

The brigade, whose headquarters is at Vienna, is attached, for disciplinary purposes, to the Second Army Corps, but in all other respects it receives orders directly from the Minister of War.

The aeronautic establishment, for administrative purposes, continues to be attached to the first regiment of fortress artillery.—*From Revue Militaire des Armees Etrangeres, Janvier, 1910.*

DIMENSIONS OF AN ARTIFICIAL WATERWAY TO CARRY A KNOWN VOLUME

BY

GENERAL H. L. ABBOT

When, as in the case of a canal feeder, an irrigation ditch, or the head and tail races of a water power establishment, the local conditions determine the slope to be given to the water surface and the maximum volume to be accommodated, the economical problem arises what should be the relative dimensions of the cross section to require the minimum amount of excavation, and hence the minimum outlay. The usual section varies from a rectangle in rock to a trapezoid in softer materials, the slopes of the latter governed by the nature of this material. The questions what should be the relative depth and width, and (where there is a choice) the precise slope of the sides, naturally present themselves to the engineer. They should not be fixed arbitrarily, since the form of cross section exerts a considerable influence upon the volume of flow, and what is wanted is the maximum volume at the minimum cost. A problem of this kind arose in the studies of the Comité Technique of the New Panama Canal Company in relation to a feeder line several miles long, which traversed a rolling country intersected by ravines and bordered by steep slopes often requiring additional excavation above the water line to prevent caving; my study of the problem suggested the following solution, the text being a free translation of the original document submitted to the Company. Adopting the usual trapezoidal form, let:

A = The area of wetted cross section.

D = The largest depth of water (distance between the two parallel sides).

W = The width at bottom.

W' = The width at surface.

P = The length of the wetted perimeter.

R = The mean radius, or $\frac{A}{P}$

C = The tangent of the angle made by the sides with a vertical, giving for the length of the base of each side slope, D C.

From the geometrical relations of the cross section, the first two of the following formulas result, and from their combination the last two:

$$(1) A = W D + C D^2$$

$$(2) P = W + 2 D \sqrt{C^2 + 1}$$

$$(3) R = \frac{W D + C D^2}{W + 2 D \sqrt{C^2 + 1}}$$

$$(4) D = \frac{A}{2 R (2 \sqrt{C^2 + 1} - C)} \pm \sqrt{\frac{A^2}{4 R^2 (2 \sqrt{C^2 + 1} - C)^2} - \frac{A}{2 \sqrt{C^2 + 1} - C}}$$

But to avoid imaginary values of D in equation (4), the quantity under the radical sign must be equal to at least zero. Placing it equal to zero, the following value of A results:

$$A = 4 R^2 (2 \sqrt{C^2 + 1} - C)$$

Substituting this value for A in the first term of equation (4), we have for the minimum real value of D :

$$(5) D = 2 R.$$

By combining equation (5) with equations (1) and (2), and considering the geometrical relations of the surface width, the following values may be derived for all the dimensions of cross section. They involve only two variables, D and C ; and, as we have seen, D in them has its minimum real value.

$$(6) A = (2 \sqrt{C^2 + 1} - C) D^2$$

$$(7) P = (2 \sqrt{C^2 + 1} - C) 2 D$$

$$(8) R = \frac{D}{2}$$

$$(9) D = 2 R$$

$$(10) W = (\sqrt{C^2 + 1} - C) 2 D$$

$$(11) W' = (\sqrt{C^2 + 1}) 2 D$$

In considering the value to be given to C (the tangent of the vertical angle at the side slopes) it is needful to take into account the nature of the soil, the contemplated velocity of flow, which if large may cause erosions, and the topography of the district. Thus if the bed be hard, and especially if bordered by a steep slope calling for extra excavation to prevent caving, it may be well to adopt vertical sides, making $C=0$; while if of ordinary earth in a nearly

level district, a relatively greater surface width may be preferable, say $C=1$, giving a side slope of one on one, or even $C=1.5$, giving a side slope of one on one and a half. But before arbitrarily fixing the value the engineer will naturally demand what value of C corresponds to the absolute minimum of excavation. This value may be found by treating equation (6) by the usual methods of the differential calculus, which indicates that for this minimum C must be equal to $\sqrt{1/3}$. Substituting this value in equations (6), (7), (10) and (11), and replacing D by its value $2R$, as given in equation (9), they take the more convenient forms:

$$(6)' \quad A = 6.93 R^2$$

$$(7)' \quad P = 6.93 R$$

$$(10)' \quad W = 2.31 R = \frac{P}{3}$$

$$(11)' \quad W' = 4.62 R = \frac{2P}{3}$$

Since $C = \sqrt{1/3}$ indicates a vertical angle of 30 degrees, and equation (10)' shows that the width at bottom is one-third of the length of the wetted perimeter, the section calling for the minimum excavation is evidently a hemi-hexagon. This might naturally be expected, since this of all trapezoidal forms most closely approximates to a half circle, and consequently to what is well known to be the form most favorable to the free flow of water.

The above equations throw light upon what should be the relative dimensions of cross section; but before adopting precise values in any particular case reference must be had to a good formula giving the velocity of flow in natural channels in terms of these dimensions, together with the slope of the water surface, and the rugosity of the bed. The formula of Ganguillet & Kutter is often used for this purpose, but the one given by Bazin in the *Annales des Ponts et Chaussées* for the fourth quarter of 1897 would seem to be preferable. It is based on an exhaustive study of all data then available, covering 809 standard gaugings made in Europe, America and Asia, and ranging in date from the classic measurements of Dubuat in 1782 to those of the year 1895. Being more complete and much more simple, this formula should, I think, supersede the older one of Kutter; but for present purposes there is no material

difference in their indications. The following is Bazin's latest form, in metrical units:

$$(12) \quad V = \frac{87 R \sqrt{S}}{\sqrt{R+K}}$$

In it the symbols have the following values:

V=The mean velocity of flow.

A=The area of cross section.

S=The slope of the water surface.

R=The mean radius of cross section, or $\frac{A}{P}$

K=The rugosity modulus, of which the numerical values are:

0.06 for very smooth surfaces, like polished cement, planed wood, etc.

0.16 for smooth surfaces, like plank, hammered stone, bricks, etc.

0.46 for surfaces like hewn stone, etc.

0.85 for surfaces intermediate between earth and masonry.

1.30 for earthen beds.

1.75 for exceptionally rough beds, having boulders, vegetation, etc.

Adopting this formula for V, and using the values given in equations (6) for A and in (9) for D, and remembering that when combined with these formulas (which are general for all systems of units) the resulting expression requires metrical units, we have for the discharge in cubic meters per second:

$$Q=A V=(2\sqrt{C^2+1}-C) 4 R^2 \frac{87 R \sqrt{S}}{\sqrt{R+K}} = \frac{(2\sqrt{C^2+1}-C) 348 R^3 \sqrt{S}}{\sqrt{R+K}}$$

Knowing for the projected waterway the numerical values of Q, S, C and K, this expression may be put under the following more convenient form in which, as the coefficient of R^3 involves only known quantities, and thus becomes constant, the value of R may be found readily by the method of successive approximations.

$$(13) \quad \frac{348 (2\sqrt{C^2+1}-C) \sqrt{S}}{Q} R^3 - (\sqrt{R+K}) = 0$$

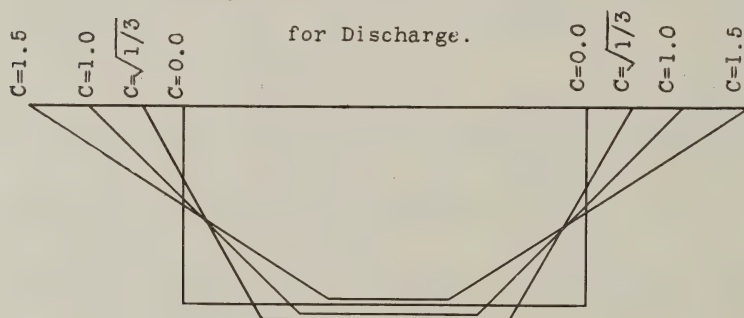
If in this expression the value of C be made $\sqrt{1/2}$, it becomes for the case of the minimum excavation:

$$(14) \quad \frac{603 \sqrt{S}}{Q} R^3 - (\sqrt{R+K}) = 0$$

Finding the value of R from equation (14), equations (6)' to (11)' will make known all the other dimensions of the cross section calling for the minimum excavation, and hence probably for the minimum outlay. By assigning other values to C and finding R from equation (13), equations (6) to (11) will make known the other corresponding correct dimensions, and thus suggest by inspection the relative merits of the different forms. Applying these computations to the case of the feeder line projected in the upper Chagres valley, for which the discharge was to be 25 cubic meters per second, the slope was to be 0.001, and the rugosity modulus, in

Practically

Equivalent Cross Sections



25 cubic metres.
Slope 0.001
Rugosity modulus 1.75.

view of the rapid tropical growth, was assumed at 1.75, the figures in the following table resulted.

Dimensions of cross section.	$C=1.5$	$C=1.0$	$C=\sqrt{1/3}$	$C=0.0$
Side slopes	1 on 1.5	1 on 1	1 on 0.577	1 on 0
Cross section (square meters)	18.30 (max.)	17.56	17.30 (min.)	18.00
Wetted perimeter (meters)	12.41 (max.)	11.33	10.95 (min.)	12.00
Mean radius (meters)	1.47 (min.)	1.55	1.58 (max.)	1.50
Depth (meters)	2.95 (min.)	3.10	3.16 (max.)	3.00
Surface width (meters)	10.53 (max.)	8.77	7.30	6.00 (min.)
Bottom width (meters)	1.78 (min.)	2.57	3.65	6.00 (max.)
Velocity (meters-seconds)	1.36 (min.)	1.42	1.45 (max.)	1.39
Discharge (cubic meters)	24.95 (min.)	24.97	25.02 (max.)	24.97

To facilitate a comparison of these cross sections, the words maximum and minimum have been added in the table, and the plate

has been prepared. The latter also makes evident the relative bearing of the different forms upon the additional excavation requisite when it is needful to sink, locally, the conduit below the general level of the soil in order to conserve a uniform slope in the water surface. Indeed, in irregular ground this may become the dominating consideration in the selection. The hemi-hexagonal cross section gives slightly more discharge, and is evidently the practical form most favorable to a free flow of water. In expensive work where the nature of the soil demands revetment, it would seem well to give it the preference. Where the route follows the contours of a steep hill side, the excess in excavation above the water level due to the larger surface width may be reduced materially by a steeper revetment of the mass above. In fine, the form of cross section is worthy of careful study, although no general rule can be formulated. Each case must be judged upon its own merits.

Strength of the Russian Railway Troops

The railway troops, which have been progressively increased in 1909, consist at the present time of 1 regiment of 2 battalions of 4 companies each, 12 battalions, 6 independent field companies, and 3 company cadres, intended to form, at the moment of mobilisation, 3 reserve battalions of 4 companies each.

The regiment, 4 battalions of 4 companies each, 3 independent companies, and 3 company cadres form part of the troops in Europe; those of Turkestan comprise 2 battalions of 6 companies each and 1 independent company; whilst 4 battalions of 6 companies each, 2 to 4 companies, and 2 independent companies are stationed in the Far East. The whole gives 74 companies plus 3 company cadres.

According to *Streffeurs Militärische Zeitschrift*, the regiment has the same effective strength whether on a peace or war footing—that is, 65 officers and 1,735 men. The European battalions on a peace footing have a strength of 28 officers and 625 men, and on a war footing 30 officers with 1,112 men and 44 vehicles, of which 1 is for officers, 2 for medical purposes, 1 for transport of sick and wounded, 10 baggage wagons which carry in addition provisions for two days, 13 commissariat wagons with four days' provisions, 5 field kitchens, 4 ammunition wagons, and 8 with field workshops.—*From Le Bulletin de la Presse et de la Bibliographie Militaires.*

TECHNICS IN THE RUSSO-JAPANESE WAR*

BY

TOEPFER

*Captain in the Fourth Engineer
Inspection*

The war carried on in eastern Asia between two great nations, on account of vital questions, brought to the battlefields, on the one side, all the forces available for service outside the country, and on the other at least an equal number of forces. The conduct of the war in all its peculiarities, depending to a great extent on the situation, conformation and geographical conditions of the theater of war, is, nevertheless, as a completely modern war, suited to the clearing up of many problems of organization, training and leading. Its teachings have already borne very rich fruits on the one side; the German method of fighting, which has been represented and continued by the adversary, has secured recognition anew.

The war will likewise decide to what extent technics, especially as applied by the Japanese, will be utilized in war by the national armies of the present time and how it can be adapted in so far as it must assume other forms. Although the last great wars have shown that the technical troops and their achievements were not always what had been expected, due to a faulty organization, the long duration of the last war, in connection with the nature of the theater thereof and the troop leading, has given an especially good opportunity for technical activity. Although no final decision is as yet possible, a short description of the technical troops and the means which may be used by the commanders is not out of place.

The conduct of the war on the part of the Russians was dependent upon the operating capacity of the Siberia-Manchuria railroad, which has unjustly been much maligned. Never was an army commander so dependent on his lines of communication, never again will an operating army have similar difficulties to contend with as regards its concentration and reinforcement.

While the one single-track line, which had scarcely been put into

*From the *Kriegstechnische Zeitschrift*, Parts II, III, and IV, 1906. Translated by Capt. Frederik L. Knudsen, Eighth Infantry, January 19, 1909.

operation in its whole length, was to bring to the front hundreds of thousands in a journey which lasted a month, its still entirely insufficient operating capacity had to be increased at the same time through the building up of dangerous and traffic-obstructing stretches; in other words, the shortening of the distances between stations by means of side tracks, water tanks and fuel bins. The materials and appliances required therefor had to be transported on the same line from great distances and in special trains. Other trains running on the military schedule, which had gone into effect, were fully occupied with the transportation of artillery material and provisions for the fortresses of Port Arthur and Vladivostok, provisions and equipment for the depots of the armies to be transported to the front and for the provision stations of the railroad itself; yes, even of many articles of necessity for the population. Thus at the beginning of the war the maximum number of daily through trains carrying troops was, on account of the conditions on the still incomplete Transbaikal railroad (daily operating capacity only six trains in each direction), limited to four, which could, during the summer of 1904, be increased to only six. Now,* on account of the shortening of the distance between stations, up to eighteen trains can be run in each direction on the Transbaikal road and on the Siberian stretches twenty trains; and of these certainly sixteen, or four times as many as were at disposal at the beginning of the war, can be used for the transportation of troops. On this account the time for concentrating an army corps has been shortened from about thirty to seven or eight days, and this explains the disinclination on the part of the Japanese to hazard the results gained by continuing the offensive against the numerical superiority which now exists.

That the continued military traffic with a small personnel has been kept up, in the first place, without any interruption worth mentioning, for over a year and a half while continually menaced; that the Manchurian armies were finally ready for battle as never before; that the organizations of troops were brought up almost to the proper strength and the Rifle Divisions (formerly brigades) were brought to the front in regiments of four battalions with 200 men to the company, and that the fortress of Vladivostok could apparently await a siege, are highly commendable performances. As compared to these, the performances of our numerous, well-organized, convenient and partly double-tracked lines, which in-

* 1906.

volved a haul about nine times shorter, are insignificant; the more so as this single Russian line had to provide for the reinforcement and evacuation of a force at least three times as large as that of one of the German armies in 1870-71. In what manner the transportation during the winter had been arranged so that, on the long journey, partly in a temperature of 30° or more below zero, only a few frost-bites occurred, has been described before in Parts III, VIII and IX of this magazine for 1904. In the same article was also described the transportation of troops and the laying of a railroad track on the ice across Lake Baikal, which had been considered impossible by many. Even if this railroad did not permit the crossing of whole troop trains, it presented the possibility of increasing considerably the rolling stock of the eastern stretches by carrying trains across. Now that the railroad around Lake Baikal, which was completed about a year and a half ago, notwithstanding the fact that the greatest technical difficulties had to be overcome, has really been opened to traffic, the through train service has become a reality. Until then the time of transportation was always prolonged at Lake Baikal on account of the necessary reloading and unavoidable jams.

In the region declared to be the theater of war, Manchuria itself, the traffic was put into the hands of the Trans-Amur railroad brigade under the supervision of the capable traffic manager, General Chorvat. This transfer was necessary because only a military personnel could be used on account of the constant danger to the railroad from the Hunghuses, who were led by Japanese, and because the increase of the rolling stock required for the concentration would have necessitated the ordering out of a strange personnel which was unfamiliar with the line. We therefore see military traffic management in operation to a greater extent than formerly; namely, over 1,157 versts (775 miles). No great disasters occurred, and all the attempts of the enemy against the numerous and important structures were frustrated by careful guarding. The guarding certainly required a large force of frontier guards in the theater of war and reserve troops on the Siberian and European stretches which came into consideration. As far back as Pensa no train was allowed to pass across any bridge worth mentioning without a military escort and with sentries in every car. In the theater of war, works capable of defense and of receiving strong detachments were built at all structures.

Nothing is reported as to whether field railroads of greater

length were built and put into operation. Perhaps the supplying railroad Tschang-tschun-Kirin-Mukden-Fuschung was completed as such. Short stretches of temporary field railroads have, however, been constructed to a considerable extent in preparing for the defense of Liao-Yang and Mukden. These were operated by means of horses. At Mukden such a field railroad across the Hung-ho facilitated the bringing in of wood to the position. About 300 kilometers of temporary field railroad was lost through the defeat at Mukden. Material for repairing horse and steam railroads was en route after the conclusion of peace.

On the Japanese side there was, first of all, a question of transporting, on a large scale, troops across the seas. The transports went to sea almost without mishaps, utilized all available space, and landed everywhere without a hitch at the places selected. That the landing at Pitsewo could be effected without interference is to be attributed both to the lack of enterprise or real deliberation on the part of the Russians and the excellent preparations of the Japanese. That they succeeded, during the siege of Port Arthur, in landing siege artillery and material and even 11-inch mortars, while no larger caliber than 15 centimeters had been considered on the side of the attacker when the works on the land side of Port Arthur were built, can also be attributed solely to the giving up without fighting of the almost untouched harbor works of Dalny.

Of railroads the Japanese had at their disposal in Korea, after the landing of the First Army, only a small stretch of the Chemulpo-Seoul line. The participation of Japanese troops in the building of the Seoul-Fusan and the Seoul-Ytschshu railroads, which have been open for traffic for more than a year, is not certain, as only one railroad battalion, belonging to the Guards division, existed in time of peace. They were probably completed by Japanese engineers under the protection of the troops. On the other hand, the work of repairing and putting into operation the stretches of the Manchurian railroads from Dalny and Port Arthur to beyond Mukden was done by technical troops. Aside from the repair work on the bed and track and at the stations, there was also a question of relaying the rails to the Japanese gauge, since no rolling stock worth mentioning fell into the hands of the Japanese before the surrender of Port Arthur and nothing new could be improvised. The Japanese gauge, which, however, suits the mountainous character of the country, is said to be only 1.067 meters. From the beginning of October such a connection was ready for

traffic from the region of Pitsewo to Tashihechiao, and very soon after the fall of Port Arthur a through connection from this fortress to the operating armies was established, so that Nogi's army could be sent forward within a short time in order to take a decisive part in the battle at Mukden. In the middle of May the railroad was in operation to Tiehling. Even the rebuilding of the 342 versts (229 miles) south of Liao-Yang represents considerable work considering the short working time. The early opening for traffic answers decidedly in the affirmative the obvious question whether the use of iron instead of wooden ties for the track in such disputed and easily attacked colonial and frontier region ought to be especially recommended, when the probable adversary has another gauge. The putting into operation was, however, made much more difficult on this account than by the destruction of the track, stations and bridges on which the Russians determined seemingly with reluctance. It may be remarked here that only the destroyed bridge across the Hung-ho had to be replaced with a military bridge and that the technical results of General Mischtenko's raid to the rear of the Japanese army in the beginning of the second year of the war could not at all have caused its commanders any inconveniences. When the network of railroads was extended, the operating of the less dangerous stretches was probably taken away gradually from the technical troops in order to have them at disposal for other purposes. After the Seoul-Ytschshu railroad had been extended as a field railroad to Liao-Yang by the technical troops, another such railroad is said to have been built, with horses for motive power, for Kuroki's army. This road branched off from the main line at Feng-huangshen to Saimachi. Temporary field railroads had to be connected for the time being with the unloading and warehouse places on the navigable rivers, the Liao-ho and the Yalu, which had been put to use as lines of communication. A whole network of other field railroads with horse power are said to have connected the sections of the Japanese positions at the Taitzu and Sha-ho with one another and with the Manchurian railroad, which had been put into operation. Sinminting was later connected with Mukden by means of a standard gauge steam railroad (64 kilometers). By utilizing the existing Russian railroad from Mukden to Fushun the line was extended to Impan (75 versts from Mukden). However, tasks of such magnitude devolved upon the railroad troops (who were certainly increased very much on mobilization) that they

could accomplish them only by the aid of the sapper battalions and other troops detailed for the purpose. It is said that every Japanese is a born pioneer; that is to say, very well adapted to technical work. The sappers are especially trained in a judicious manner for building field railroads, and are especially qualified for building these by having issued to them field railroad material. The material (width of track 60 centimeters) is carried along, the rails and ties separately, and first put together shortly before being used, in track lengths of 2 meters, which are fastened together by means of a fish plate connection which is easily secured, so that the possibility of transportation on the mountainous roads of the theater of war can be increased and desirable quickness in building result.

This solution of a question of organization is naturally conditioned by the configuration of the home country, the probable theater of war and the nature of the roads. It is difficult to form an idea of the condition of the network of roads and the problems which the improvement thereof presented to the technical troops. It could not be foreseen that the necessary work would assume large proportions. For this reason the Japanese regulations make it the strict duty of the sapper officers to study thoroughly their own country, and especially the probable theater of war, with regard to the road conditions and the means for their improvement. The performance of the work itself was made possible by the increased assignment of sapper companies to the divisions (one battalion of three companies to a division, or in a ratio of 1 : 16, as compared to 1 : 33 with us). The training of the infantry in pioneer duties had besides been carried on in such a manner with regard to the theater of war that the sapper detachments of the regiments could really be profitably used at the head of the marching columns.

Kuroki's army passed in this manner over the mountain roads of Manchuria from the Yalu to Liao-Yang and farther on to Fushun and Nodzu's army between Dagushan and Haitsheong, and the latter army had to place in condition for use a number of cross roads. All these roads resemble more or less narrow wood paths, which, on account of ground and slope conditions, especially in heavy rains, were almost useless and had, first of all, to be widened in the form of a gallery (of which the Japanese road-building regulations give a corresponding sketch). The roads which crossed the more level stretches, even the Mandarin roads, were no better.

Like the deeply furrowed Russian country roads, which have an endless width, they change in the heat of spring and during the time of tropical rain storms into bottomless quagmires, to become quickly, under the influence of drying winds and a hot sun, a series of knee-high ridges with stone-hard edges, on which a man finds it difficult to walk even by day. Resting occasionally as sunken roads on the beds of ravines, flooded by the frequent, sudden swelling of brooks and rivers, having nowhere a solid surface, they had, first of all, to be thoroughly drained. Suitable material for making a solid surface was many times lacking on the spot; only the widely distributed kaoliang was at hand, and it seems, as in the case of fortification work, to have provided a temporary improvement with its wood-like stems. Use was often made, for heavy wagons, of the plank road described in the road-building regulations, with a foundation of sand, gravel or broken stone and wedging. In front of Port Arthur quite difficult road building had to be carried on through the exertion of the technical troops sent thither, in order to bring the heavy artillery into positions commanding the fortress. The roads used by the troops as lines of march were enlarged and improved throughout so that the armies had at their disposal, besides the railroads (Dalny-Mukden-Tiehling, Yingkou-Siminting-Schaschedzsy-Liao-Yang-Tiehling), and the navigable water courses (the Liao-ho and the Yalu), serviceable land march lines with suitable cross connections.

Although the demands of the Japanese on the serviceableness of the roads were rather small and could be made so because their artillery was, for the most part, mountain artillery, their trains made up of light carts and the field equipment and baggage carried along on pack animals (even the soldier's field kit was at times carried by Korean coolies), an enormous amount of work in railroad and road building was nevertheless carried on during and after the march, which is unequaled. Their methodical conduct of the war permitted no neglect in this respect and shows therefore a far-reaching utilization of technics. But it must also be admitted that this was fully justified when it perhaps brought the Japanese the greater results of rapid strokes against the unprepared and at first smaller numbers of the Russian troops.

A participant* describes clearly in what manner work has been performed on the Russian side in the developing and improvement

*Sascharoff: Road and Bridge Work during the War in Manchuria, Engineer Journal, Nos. 7 and 8, 1905.

of the network of roads under the direction of the many engineer officers in the field road bureau of the armies. The stretches of road were divided into sections and were repaired, by the aid of sapper detachments and by hired native laborers, preferably by means of careful draining. The Russian is also, on the whole, just on account of the defective development of his own country, suited to perform the most necessary work in road improving. He has even known how to obviate the inconveniences of the mountain roads, but his trains and many troop wagons were certainly left standing here and there, or had to be destroyed when he retreated.

The assignment of technical troops (sapper battalions) to the fighting part of the army corps is the same as with us. Since the strength of the companies is smaller, the presence of the pontonier battalion (see below) changes the ratio only a little. The sappers, however necessary they were, especially in a retreat, for repairing the roads, were not available therefor, because they were principally employed in fortifying the main and rallying positions. The work, which consisted principally in building low embankments at the bridge approaches, had to be performed by the pontoniers.

Military bridge building necessarily found a large field of operations in a theater of war with such poor road connections and such numerous and unregulated river beds, which often filled up with surprising rapidity on account of the heavy rainfalls in the rainy season. Even if the rivers can be forded in most cases, their sudden rising in connection with a raging current, when the banks are overflowed, makes the necessary bridge work especially difficult.

One of the first interesting events of the war was the crossing of the Yalu by the Japanese, interfered with by an effective artillery fire from the Russians. This crossing may, as regards the tactical situation, be compared with the crossing of the Elbe at Wartenburg by Blucher (October 3, 1813, trans.), and, as regards the technical difficulties, with the building of bridges at Arnis* (cold and floating ice). It can, however, not be understood why the crossing had to be forced in the face of the enemy at Ytschshu, while at distances of 15, 65, and 80 kilometers farther up stream, arrangements therefor had been made beforehand, and why the element of surprise was utilized so little. Only a few troops had been sent across to the island opposite the main point of crossing and further

*A village in the duchy of Schleswig, Germany, where Prince Friederich Charles built several bridges across the Schlei in order to turn the Danish position, March, 1864.

reinforcements were not sent until the bridge building had been accomplished under the protection of heavy artillery, which had been brought into position, and an impression had been made on enemy's left flank. Finally quite a number of crossings of prepared and emergency material were at disposal across the several branches of the river. The nature of the Japanese military bridge material,* aside from the conditions as they existed on the spot, explains the isolating of the few covering troops who were sent over first, and the long time consumed in building the bridges. Made very light and put up in loads for pack animals for transportation on difficult mountain paths, it is certainly not very well suited to the unexpected crossing of infantry with comparatively quickly moving and heavily loaded row-boat ferries. For this purpose are used, in their place, according to the Service Regulations for the Technical Troops,* forcibly collected boats, the bringing together of which naturally renders an operation of surprise especially difficult.

I do not know how great a bridge length the ponton train of a sapper battalion carries along, although from the number of 170 one-horse carts, which has been given in the Russian Report of the Armed Forces of Foreign Nations, and in No. 3 of the Engineer Journal for 1905, the conclusion may be drawn that the ponton train, on which the other field equipment of the sapper battalions seems to be based, carries in no case more, but probably considerably less, bridge material than our corps bridge train. On this account the number of bridges, which had to be thrown quickly across the 200-meter wide Yalu, was, of course, limited.

The Japanese emergency bridge construction conforms entirely to the models used by us; the emergency bridge regulations are partly translated literally from ours. In the sapper service regulations there are, however, illustrations which elucidate the use of quite light material, to be found in the locality, for bridges of the simplest kinds and of small length.

On the Russian side there is said to be in every army made up of European corps, one ponton battalion of two companies with material for 224 (266) meters of bridge.† Iron pontoons are used

* Compare the Technical Service Regulations of the Japanese, Part IX of the *Kriegstechnische Zeitschrift* for 1905.

† Two hundred and sixty-six meters by inserting six auxiliary trestles.

which seem to have stood the test so well in the war of 1870-71 that no material changes have been made in them. Every sapper battalion has, besides, two light bridges, 21 meters long, suitable for all arms of the service and consisting of a few trestles and small pontoons without bows (Colonel Meiszner's system), which are carried on vehicles drawn by three horses. Ingenious people are continually experimenting with the construction, but the commander of the East Siberian Pontonier Battalion No. 1, Colonel Kisseljeff, makes the disappointing criticism of this light bridge train that it was not used at all from Haicheng to Mukden, because rivers which were suitable to it as regards width, depth and the nature of the banks did not exist. A sapper company commander stamps it even as a march-delaying, useless and interfering addition in a mountainous country like Manchuria.

At the end of 1904, there were (according to Colonel Kisseljeff**) in the theater of operations only the East Siberian Pontonier Battalion and the three pontonier companies of the East Siberian Sapper Battalions, Nos. 1, 2 and 3, with suitable material. Since then Pontonier Battalions Nos. 2 and 3 have been formed from the last-named companies. The European Pontonier Battalion No. 1 with a strength of four companies and a new equipment, which was loaded on two-wheeled carts and consequently similar to the Japanese, proceeded to Eastern Asia at the end of 1904. Thus the peculiarity of the theater of war was taken into consideration in this respect and the suitability of the Japanese bridge material acknowledged conditionally.

It appears from Colonel Kisseljeff's account that the need of bridges and prepared bridge material was strongly felt at Liao-Yang and Mukden, so that material used for instruction, but without draft animals, was drawn from Harbin. A temporary replacing of continuous bridges by means of ferries was nevertheless necessary. The self-sacrificing work of the pontoniers made possible the withdrawal of the troops to the right bank of the Taitzu at Liao-Yang. The loss of material was, however unavoidable, principally because the pontonier companies with their bridge trains did not form a part of the army corps organization. For this reason and because the pontonier troops were not at hand in sufficient numbers, there was also several times a time-wasting

* The Russian Engineer Journal, No. 2, for 1905, and the *Kriegstechnische Zeitschrift*, Part X, for 1905. The Pontoniers in the Far East from July 2-15 to December 12-25, 1904.

sending away and calling back,* while again there followed, after days of enormous exertions, longer periods during which the special troops had nothing to do. For these reasons and because the men called out have, as already mentioned, an aptitude for technical work developed by the habits of their life, the retaining of special troops for bridge building and kindred work certainly seems superfluous. The emergency bridges built by the sappers demonstrate this, as well as the ability of the troops of all the arms, to prepare river crossings by themselves; for instance, during the raid of Mischtenko's force to the rear of the Japanese. The many fords in the Manchurian rivers and the training of the cavalry in swimming, made such crossings very much easier, to be sure.

As supports for emergency bridges, which were partly built for large columns, were used junks, lighters, rafts and trestles. The trestles were almost exclusively timber trestles (cribs), for which there seems to exist such a fondness among the Russian technical troops, that they are called "Russian" or "ordinary trestles." As the severe winter set in "ice bridges" were prepared, by strengthening the ice covering, and these were used exclusively. Many persons emphasize the fact that the ingenious bridge constructions, of which especially the very theoretically pregnant, voluminous regulations have a surplus, were used at no place.

The theater of war offered every opportunity for an extensive use of the technical adjuncts for the transmission of information. The co-operation of the army and navy at and before Port Arthur; the advance of the Japanese on broad fronts with large intervals across the mountains in Manchuria; their widely extending turning movements and the counter placing of Russian corps and detachments; the great extent of front over which the principal battles were fought, gave both sides the same opportunity to utilize both the forces and the means at hand for the information service and to test new appliances and inventions. It must also be acknowledged that on both sides, in the Russian electro-technical experimenting and school companies, as well as in the Japanese School Telegraph Battalion, much has been accomplished to make suitable innovations useful to the army. While, however, in Japan the preparation in this respect for the long-expected war was easier and carried on more methodically, and technics in its present state

* These and similar experiences are probably to be attributed to the organizing, ordered on May 13, 1905, of third companies, as cadres for four reserve pontonier battalions, in the European battalions, Nos. 3 to 7.

could at once be made use of, Russia had fallen behind and had to recover during the course of the war what had been neglected.

Of telegraph troops there were stationed in eastern Asia at the outbreak of the war, aside from the fortress telegraph troops at Port Arthur and Vladivostok, the telegraph companies of the First and Second Siberian Sapper Battalions, Nos. 3 to 6, and the mobilized European sapper battalions had at their disposal two pole and one cable detachment, each with 90 kilometers of wire, and they carried their material along in light carts, which had already stood the test in the campaign in 1900, in the same theater of war. The telegraph companies had besides, according to the regulations, heliographs and Mangin signal lamps in their equipment, which had been used successfully in the campaigns in Central Asia, and constitute together a very useful substitute for defective telegraph lines and facilitate the connection of the outposts and the extreme flanks with the cavalry masses pushed forward. During the war there were organized, with a similar equipment, in the East Siberian Reserve Sapper Battalion, two more companies which were sent forward to Harbin. In 1904, two East Siberian Telegraph Battalions were further organized, one in June and one in December, either as an army telegraph organization or at the disposal of the commander in chief. During the period from November, 1904, to March, 1905, three independent companies for wireless telegraph purposes were organized, and the telegraph half-squadron and the telegraph sotnia, sent out by the order of May 18, 1905, arrived in the theater of war, the former with its equipment loaded on wagons, and the latter with its equipment on pack animals.

While the independent telegraph companies thus put into use the results of the noteworthy experiments of the electro-technical company with the army's wireless telegraph system,* the half-squadron and sotnia were equipped with light telegraph, telephone and visual signal apparatus. They are intended to establish connection between the higher commanders, to whose staffs they are attached, in moments of necessity during the march and in action when the other telegraph organizations are not able to do so away from the roads on account of their equipment. They have with them 32 kilometers of cable and equipment for four telegraph, eight telephone and four visual signal stations and are said to be able to lay lines at the rate of 10 to 12½ kilometers an hour under

*Between St. Petersburg and Narva, and, more recently, with the Marconi apparatus between St. Petersburg and Vujschni Volotschok, 361 kilometers.

favorable conditions and over short distances at the rate of 21 kilometers an hour. The Novoe Vremja complained that a highly important invention, wireless telephony, which in the tests during the maneuvers of 1900, 1901, and 1902 had worked up to 15 to 20 kilometers, was not used. The Caspian regiment which made these experiments at its own expense and had been sent to Eastern Asia would certainly have been in a position to prove the suitability of its apparatus for war.

The letters of a telegraph officer* give comprehensive descriptions of the work of the Second East Siberian Sapper Battalion belonging to the Third Siberian Army Corps, on the left flank of the position at Mukden. The lines connected the outposts with the rearward reserves of the regimental section and were maintained until the troops had to evacuate the position after the continued attacks of the Japanese. The cable detachment lost only ten men altogether in this case. The central station handled about 500 messages with over 20,000 words. Especially inconvenient was the fact that only thirty to thirty-five men who could read were available for the ten to twelve, sometimes eighteen, telephone stations of the cable detachment. The Chinese names often caused a great confusion in the messages. On the other hand, fault is found that the telegraph companies worked too slowly and could generally connect the staffs only, and that the pole detachments especially had such unsuitable material that they could not be used very easily during the march.

This condition is said to have made itself felt very soon. The necessity for using the telephone very extensively became apparent. The outpost telephones sent to the fighting troops proved to be useless, so that the regiments and artillery groups procured equipment out of their own funds. Now that this telephone (similar to the patrol system) has shown itself to be extremely useful in position warfare, it is recommended that equipment and six to ten versts of cable be issued to all regiments, batteries and staffs. The method of signaling introduced in October, 1904, does not seem to have been generally adopted.

In Port Arthur † abundant telegraph material was on hand, so that the transmission of information and orders could be kept up to date. A wireless telegraph station was also at hand, which main-

*The Invalid, Nos. 15, 20, 79, and 80 for 1905.

†The Fortress Port Arthur, Kriegstechnische Zeitschrift, Part VI, 1905.

tained communication both with parts of the fleet and with the station of the Russian vice-consulate at Che-foo.

It has become known that on the Japanese side the infantry patrols advance with a telephone equipment, carried in a light knapsack and having a thin wire like that which our cavalry uses and which can be unwound and cut in as soon as they have to send a message.

There can be just as little doubt that this kind of information transmission has stood the test, as that the different Japanese armies had an excellent working system of exchanging information with one another. Otherwise their faultless co-operation in the battle on so large a front would have been inconceivable. It is also stated in No. 48 of the *Invalid* for 1905, that an extensive network of telegraph and telephone wires was working and connected with the lines of communication. In the battle of the Shaho, on October 11, 1904, the staff of the 10th Division was, owing to the certain information service, continuously in communication with the staffs of the various regiments, and this was always the case. Aside from the School Telegraph Battalion, consisting of two companies, no telegraph troops at all are said to have existed in time of peace. Military telegraph and telephone detachments were, however, organized on mobilization, as provided by the Japanese field service regulations. Only the methodical, slow advance can, however, explain the considerable efficiency of these troops under these conditions. In this connection might be mentioned that the Japanese army undoubtedly had automobiles; the mountainous character of the country did, however, limit their use greatly. The Japanese censorship, which has made silence concerning all military matters its duty, did not, unfortunately, let more exact information be known concerning the service of information and its means.

The objection is raised, on the other hand, that the better the transmission of information and orders, the greater is the danger that the higher commanders will know too much and will want to supervise and take away from their subordinates the feeling of independence and the courage to shoulder responsibility. Kuropatkin seems to have made this mistake at Mukden. This was, however, excusable, because the commander in chief and the army and corps commanders did not agree.

The search-light was called upon to play a quite especially important part at Port Arthur. It was indispensable in searching the roadstead and, aside from the first attack, it caused the Japan-

ese torpedo boats and fire ships to be discovered in seasonable time by the ships and batteries. It must have been used effectively to no less extent from the high-lying fortifications of the land side, in connection with illuminating rockets and starlights, to illuminate the foreground. It seems, finally, to have done pretty good service here and there in the positions at Liao-Yang and Mukden, which were strengthened with provisional and field fortifications. This is confirmed by the order of April 20, 1905, which places a search-light detachment with ten stations at the disposal of the commander in chief. To this are assigned two officers, thirty non-commissioned officers, ten lance corporals, thirty privates, fifty drivers, thirty-four non-combatants (mechanics and laborers), one hundred and thirty horses and thirty vehicles. As it was used effectively on the water, it may also be assumed that the search-light was used on land and from land to sea (at Port Arthur) for transmitting information and orders by means of direct flashes or by flashing the Morse alphabet on the clouds. A transportable observation tower, which was tested by the Sapper Battalion of the Guard, and which was also intended for sending messages, was shown to the Emperor in April, 1905, and was evidently to be used by the search-light detachment. A similar use of the search-light may have been made on the Japanese side, since the camp and road building regulations point out expressly the use of observers for the information service.

The Japanese search-lights worked nearly every dark night and interfered with the work of the Russians in their positions and likewise with the activity of the hunting detachments.* During the night of February 27-28, 1905, a search-light at the village of Sandjasa compelled the postponement of the attack on the railroad bridge for fully three hours.

Little has been made public concerning the use of ballooning for military purposes. This must necessarily seem rather strange, as the balloon had rendered besieged Paris special service in 1870-71, and balloon troops have since been organized in all armies. In Russia there existed before the war only the balloon school park, whose task, besides the training of the personnel, is to organize field balloon detachments. There were, besides, in the fortresses on the western frontier a number of permanently organized fortress

*The so-called hunting detachments are used for reconnoitering far in advance, often taking the place of reserves for infantry and cavalry patrols, occupying outlets of forests and defending lake narrows and bridges. (Translation.)

balloon detachments. In Port Arthur, incredible as it may seem, nothing was on hand, because it was readily believed, for the sake of economy, that the high hill tops around the fortress offered sufficient view. The opinions changed shortly before the war, but the material shipped on the steamer *Manchuria* fell into the hands of the Japanese, and a second shipment sent by rail did not reach its destination. The ingenuity of a Lieutenant Lavaroff, who had just finished the course at the school park, succeeded nevertheless in manufacturing two captive balloons on the spot and using them several times.

The use of the existing balloon material in the field, especially in the East Asiatic theater of war, was interfered with on account of its weight and the unsuitability of its vehicles for the bad Manchurian roads. They are supplied with hydrogen gas generators using iron filings and sulphuric acid, and they can not decide to carry along the gas, ready for use, in gas cylinders. The difficulty which exists of replacing the gas consumed and the necessity for decreasing the train as much as possible makes this seem not wholly unjustified, however little suited to the purpose the old materiel was on account of its weight. (The gas generator is said to weigh 2,600 kilograms, and for generating 1,000 cubic meters of gas are required 5,700 kilograms sulphuric acid and just as much of iron filings. The field balloon company, organized by the order of April 21, 1905, did, however, take the field with the old material.

After the construction of a light train at the expense of a private citizen (*sic*) had been accomplished, in which train the whole apparatus, including the considerably lightened steam winch, is loaded on two-wheeled carts, the organization of the 1st East Siberian Field Balloon Battalion was ordered on July 9, and A. M. Kovanko, the meritorious commander for years of the school park, was appointed its commander. The order for organizing a second battalion (in the second Manchurian army) followed on October 24, and on April 14, 1905, the order for organizing a third battalion. With the new apparatus the hydrogen is generated by treating aluminium with caustic hydrate of soda. The spherical shape of the balloon has been retained. It carries, with a capacity of 640 cubic meters, two men, and in a strong wind, one man; permits of good observations up to a wind velocity of 7 meters per second and can, in a favorable wind, change position at the rate of 7½ kilometers an hour.

The commander of the first mobilized balloon company had, in the first place, to contend with the lack of judgment and the prejudice of the station commander at Liao-Yang before he succeeded in getting away and making himself indispensable. Then the commander of the 10th Army Corps considered that he could not longer dispense with the balloon. It succeeded, during the battles at Liao-Yang, in determining exactly the position of the Japanese batteries, discovering in time the turning movements and also the well-concealed Japanese rifle pits. Similar favorable results were obtained by the 1st Balloon Battalion at Mukden, as "the position of the hostile lines, redoubts and batteries at Sandepu could be located here and there in every particular." It had been necessary, after arrival in the theater of war, to have a two weeks' course of instruction at Harbin precede its use in front of the enemy, because only a few of the men were familiar with the handling of the equipment.

Long-distance photography was usefully employed from the balloon. The Hamburger News stated that the photographing from balloons was done with an apparatus invented by a Dresden firm, which by means of seven cameras, which open simultaneously, produces a panoramic picture. The cameras are grouped around a central camera which is directed downwards and are opened by means of an instantaneous shutter which is to be operated, from the ground also, by means of electricity, as soon as the apparatus is in a horizontal position. The Japanese tried to protect themselves from the inquisitiveness of the balloon observers mostly by firing, but without result, for the most part. They also endeavored to conceal their positions by means of heavy smoke. The balloons were also used for signaling purposes.

On the Japanese side there are likewise balloon detachments, according to their field service regulations. These detachments were probably mobilized from the Telegraph School Battalion. It was, however, stated in a lecture, delivered at the Engineer Academy on April 11, 1905, that Japanese balloons had not been observed in the theater of operations in Manchuria. In the middle of July, 1905, a Japanese captive balloon was mentioned as being in the position southeast of Nanchengtzu.

Carrier pigeons must have been used in and before Port Arthur for establishing a quick and certain auxiliary means of communication from the advanced positions to the fortress and perhaps between the fortress and the field army. In no other manner than

by means of carrier pigeons, post or wireless telegraph, can be explained the rapid transmission of Stoessel's telegram and the maintaining of communication with the outside world. The carrier pigeon sport has probably been fostered generally over the whole of Russia, just as in Vladivostok before the war, and has been utilized for military purposes during the war. A first-class station with 1,000 pigeons was established at Vladivostok last fall. It is not surprising that a surreptitious communication through Japanese agents was held with the besieged fortress of Port Arthur by means of a carrier pigeon post. After the discovery of such a one it is said that the whole male population of a hamlet lying within the limits of the Russian position was punished with death.

Camp shelters showed themselves to be necessary to a great extent. The piercing cold of the Manchurian winter, with a temperature falling to -25° C., which brings little snow but ice-cold north winds, proved that the partially destroyed native farm houses, and even those which had not been damaged, were entirely unsuitable as living places and caused the early erection of heatable dug-outs everywhere. If the arrangement of these, which had also been tried in the Crimean war, is nothing new in itself, the number and size of the dug-outs represent, on both sides, a considerable amount of work, which was not the case in the above-mentioned war. The organizations which arrived during the cold period and were compelled to work themselves down into the deeply frozen ground with picks and crow bars were badly off. But, "let him who would learn to pray go to sea." The officers also preferred the warm dug-outs to the comparatively well-aired native buildings. The sanitary conditions in these dug-outs were not bad; their occupants were, at any rate, protected from cold and frost-bites.

In the positions the camp-like prepared bomb-proofs served the same purpose. There sufficient attention was apparently not paid to a very important matter. However disgusting the subject is, it is nevertheless necessary to call attention thereto. Latrines were lacking. The defiled passages and connecting trenches became, as the frozen waste water began to thaw and emit a stench, almost useless. The disgusting liquid flowed with a natural flow even into the shelter trenches and compelled the use of enormous quantities of disinfectants. The positions had to be partly given up when the Japanese attack was still a week off.

It also became necessary to build shelters on a large scale for the horses, and here the kaoliang was again a quite good substitute,

because lumber was difficult to obtain. The preparation of camps is pointed out as an important duty of the Japanese sappers. On the Russian side the troops themselves seem to have been made responsible to a great extent for the arrangement of their winter camps, and this is the most natural. Both sides pinned their hope to the destructive influence of the winter on the adversary, but both showed themselves fully equal thereto, although the military activity was limited to outpost service, skirmishes, desultory bombardments and enterprises on the part of volunteers and the hunting detachments, and partly also to demolition work. Only General Mishtchenko's raid and Grippenbergs's unsuccessful offensive movement are the larger enterprises of this period. While a victory would have exposed the attacker too much to the influences of the climate, and a defeat would have caused enormous sacrifices, there was still an inactivity in the operations while in winter quarters such as is now no longer even to be thought of. The necessity for avoiding such inactivity a second time seems to have been one of the reasons for the unexpected yielding of the Japanese at the peace negotiations.

It could be foreseen with certainty that the war would present opportunities for a very extensive use of field fortifications. The war of 1877-78 demonstrated the necessity for the spade. Now the endeavor must show itself on the Russian side to take advantage of the experience gained there, and this the more so in view of the fact of the progress in the technics of weapons and the adversary, who had been trained throughout in a modern sense, for the most part according to our regulations, promised hard-fought battles replete with losses. It became then a question of compensating for the disproportion in numbers by means of a skilful use of fortifications. While there was much to make secure and still more to cover, which was imperative, the fortifying of a very far advanced main position, Liao-Yang, which was already from the first turned by the concentration of the Japanese, became absolutely necessary. The tendency to make turning movements remained on the Japanese side. On the Russian side nothing better was known to oppose this than to extend the fortifications and make them ever stronger. The war has demonstrated that it was impossible to assault them, especially after an insufficient artillery preparation (the rule). Only the still more widely extended turning movements remained. The Japanese, however, did not dare leave the long fronts quite unemployed—the position of the 1st Army Corps at the Shaho covered a

space of $8\frac{1}{2}$ kilometers. The stretches of ground captured had naturally to be held so as to prevent a view behind them. Hence their fortifications, against which the few attacks, which were not made with sufficient force and persistency, brought only partial results. Thus the remarkable condition presented itself that both adversaries faced each other for months during the dreary winter with their outposts short distances apart, in places at the middle and even at the short rifle ranges, and the positions were strengthened with ever-increasing care. Notwithstanding the final similarity in the arrangement and forms, an essential difference between the adversaries can be established in this respect, viz: that the Russians fortified themselves, while the Japanese intrenched themselves. The former prepared positions to be decimated therein, the latter to ward off a counter-stroke coming at an inopportune time, and to build up their offensive power in them. The Russians were not able to free themselves from their positions early enough. The fortifications dominated the commanders, and they let themselves be dominated willingly, no matter whether the accusation applies to the commander of the army or the subordinate commanders. They paralyzed action and obscured the view of the objective. They were considered proof against capture, and yet the deduction was not made therefrom that their garrisons could be reduced to the lowest limits so as to be strong enough on the flanks. Baffled by unfavorable conditions the positions had to be given up at many places without a real struggle as soon as the turning movement became effective again. Where such a struggle has been carried through it has again been demonstrated that a well-fortified position can not be taken by field warfare alone. Only a continued fire of heavy artillery and a step-by-step advance of the infantry under the protection of this fire will bring about its fall.

Our drill regulations warn expressly against the premature use of fortifications. If this paragraph is closely adhered to, the time which is necessary for preparing good fortifications will mostly be let slip by. On the Russian side this danger was never incurred, but, while the time was thoroughly employed, the error of overdoing it was committed. At Liao-Yang three lines were built, one in front of the other, a first front on the slopes of the heights south of the town, one around it and one in front of the Taitzu bridges. That is, in keeping with the Russian custom not inconsiderable value is placed on the fortifying even of a line of resistance.

If it is considered that the outposts of the advanced position in

many cases still have their special fighting positions in which they are to hold out at least for a short time, there are even four lines. At Liao-Yang there was a desperate struggle for the outpost position only, and the main position was sacrificed. And yet how carefully this had been prepared.

The officers of the Engineer Corps gain, through their three years' course at the Engineer Academy and their practical work in fortress and other building construction, certainly much solid knowledge and much experience in building, but they lose too easily their touch with the troops and the comprehension of the simple, and yet every fortress as well as every field position must be simple and clearly arranged. It is absurd to draw on troops posted on certain lines for the defense of other lines. It is absurd to want to flank a line from an open position when we can be brought under fire ourselves and it is not at all necessary with the present effective weapons. Still the main position of Liao-Yang was thus concocted, and if drawn on a small scale map, would look much like a sentence in Sanskrit or Chinese characters than a field position. This position, in which no uninitiated person could have found his way, did not, unfortunately, have to stand the test. The Japanese positions also, except parts on the Shaho and Hungho, were, unfortunately, not put to severe tests. Here are found simple, long, straight lines with good fields of fire, flank protection by means of echeloning, and only here and there a redoubt or a piece of a rallying position.

The artillery, as the armament of the position, was correctly posted in rear of the infantry line on the Japanese side. On the Russian side it was posted on the infantry line, as, for instance, at Turentcheng and by the 10th Army Corps at Zegon, in the beginning of the war. This distribution led naturally several times to considerable losses. Later it was known how to protect the artillery better. Several positions seem to have been prepared for the Japanese artillery which may have been necessary, at any rate useful, on account of the wide fighting fronts.

The parts of which the Japanese positions were made up are: rifle pits with shelters and covered trenches with splinter-proofs, zigzagged and traversed connecting trenches and occasionally redoubts like those still prescribed by our field fortification regulations. The relative forms are on the whole like ours. The forms of shelters are somewhat more varied. The shelter with an inclined roof resting against slopes and buildings is especially rec-

ommended. The shelter trench has a lower covering height for standing men, and the lying down trench has been retained in view of the fact that the attacking infantry will shelter itself by digging in almost every firing position. The cover for the guns is, according to the regulations for the sapper work of the field and mountain artillery, arranged somewhat differently from ours. Special stress is laid on the preparation of a firm footing for the wheels and that the parapet of the gun pit be not made of loose sand which flies around when firing.

The Russian forms are much less adaptable to the ground. Where this is utterly disregarded by building closed fieldworks having a regular trace and the cross-fire effect of the fortified lines is striven for, the adaptation is made difficult, if not impossible. The closed fieldwork is in memory of the Grivitzka redoubt before Plevna, a holy relic of the field fortification regulations which must not be altered. It is a pity that the Japanese artillery, which was for the most part mountain artillery, could not on account of the small effect of its projectiles and the too long ranges, deprive the fieldwork of all credit as a bullet stop.

The cover for the guns (circular shape), which differs from ours, has been exposed to little in the artillery actions to justify any expression of opinion for or against it. The many forms of shelters described in the regulations have certainly been used. It is also mentioned that roofs as shelter against shrapnel fire were placed so high that the required space for loopholes was left between the line of fire and the under side of the roof, and these could be held by posts and parts of troops of the foremost line under artillery fire. Both adversaries have utilized the advantage of retaining steep parapet and trench slopes in the firm ground formation. Where the ground was rocky or frozen hard, rocks, clumps of earth or sacks filled with earth were resorted to. The Japanese have, when attacking, even dragged sacks filled with sand forward to the last firing position.

The arrangement for the defense of existing cover became apparent, especially in the positions on the Shaho. The villages and hamlets on the line were fortified, and even the strong and plainly visible mud walls have been used, contrary to the opinion held by us. Against these artillery fire was not sufficiently effective, and thus it happened that, at the village of Sandepu, during Grippen-berg's partially offensive movement during January, apparently a few Japanese companies were able to maintain themselves in one

section against very much superior numbers, after the main part of the place had been given up. The Putiloff hill at Shahopu on the south bank of the Shaho was made a supporting point more nearly in our style, but was impaired very much by the Russian system of cover. Its capture and retention is a bright event in this war which has been so unlucky for the Russian arms.

In fortified positions there comes into consideration the building of numerous look-out towers and observation platforms and the preparation of lines of information (see above). The kaoliang brush is cultivated over extensive level stretches, and hid every hostile movement, and the attempt to cut it down was a waste of time. In return the kaoliang, which has already been mentioned several times before, offered a very suitable material for shelter and revetment work, and it was also used for concealing the earth taken out of the trenches.

Both sides endeavored to make the positions as inconspicuous as possible by adapting them to the ground, digging down deeply into the ground and concealing them carefully. Tree and brush masks on wooden frames were dragged in front of the Japanese batteries. In carefully prepared sham works, dummy guns of wood were ingeniously placed and kaoliang fences and twine entanglements were built to represent obstacles.

Obstacles have found an extensive use as an important element in the fortifying of positions during the whole war, both in single sections and in long series, as well as in enclosing fieldworks, and they were, on the Russian side, not only at Port Arthur, but also in the works at Liao-Yang, arranged in three lines to prevent an assault to a certain extent. Wire entanglements and barbed wire fences were used most extensively, abatis less so. On the Russian side the "trous-de-loup," pits dug cone-shaped to a depth of a man's height and arranged chess-board fashion with strong pickets at the bottom and partly covered with wire entanglements, have eked out their regulation existence. On the Japanese side are said to have been found lately, placed in pits and covered, palisade fences turning around a horizontal axis and rising vertically when stepped on. Both adversaries impute to each other the leading of strong electric currents through single wires of the wire entanglements. The wire entanglement of barbed wire was found by the Japanese to be the most disagreeable obstacle after infantry detachments had several times become entangled in them at unexpected places and had been shot down at the closest ranges.

Each sapper company had in its portable intrenching tool equipment fifteen wire cutters which, in view of the present wholesale use of wire, might be recommended, as well as the carrying along of a larger number of these tools in the division bridge train. These tools were used many times by the demolition troops while they had to lie on their backs to work.

Fanciful stories have often been circulated concerning the use of mines as obstacles. A report thereof, published in the *Invalid*, leads, however, to the conclusion that mines, whether they were contact mines or land mines which were to be set off automatically or by an observer by means of an electric current, have been used very systematically and extensively not alone in front of Port Arthur. They were placed in conformity to the regulations, from 50 to 200 meters in front of the works, although often closer, were attached by groups in two series to one conduit or put closer together as contact mines and contained a charge of up to 25 kilograms of powder or guncotton buried to a depth of about 2 meters. They were also placed in iron receptacles close beneath the surface of the earth or in bore-holes radiating from the fortress ditches. Fougasses throw masses of rocks to a distance of 150 meters, otherwise the effect of the mine is altogether local. A single mine will scarcely disable more than twenty men and will kill but few of them, but will produce painful wounds. On the whole the moral effect which the detonation of the mine produces has, like always heretofore, been greater than the material loss. Attempts against mines from above are always problematical—the driving of cattle across suspected places, as was tried by the Japanese in front of Port Arthur, temporarily raised the meat famine of the enemy under certain circumstances. Japanese land mines seem not to have been actively employed, but there is no reason for doubting their use. When Sandepu had to be partially evacuated, the Japanese are said to have left behind them prepared explosive charges with timed fuses in different houses and in inconspicuous places, not to mention other charges with ingenious arrangements for firing, such as the closing of an electric current by picking up any conspicuous object.* As regards the use of mines, nothing is to be said except that fougasses are not to be despised. The Japanese regulations for demolitions are, for the most part, a literal transla-

* Taburno: *The Truth about the War*.

tion of ours and their explosives are at least fully equal to ours in effect.

The remarks concerning field fortifications in the theater of operations can certainly be summed up by saying that the Japanese types and their use bear the trade-mark, "made in Germany;" that they do not offer us anything new and that they have stood the test well. The Russian field fortifications together with their voluminous regulations therefor have not met with universal approval. The commander in chief in the theater of war did, on June 1-14, 1905, call for an expression of opinion from all organizations of troops as to the noticeable lack of types of field fortifications, and the types most approved and the desirable changes in portable and transportable intrenching tools, their distribution and number. It seems very evident that opinions were forthcoming under the fresh impression of the experiences gained. It is to be hoped that they will be published very soon. It was not always the duty of the troops designated to fight in a position to perform the work of fortifying it. At Liao-Yang, for instance, parts of the 10th Army Corps were used until they were sent back to their corps which was posted on the left flank of the Eastern army opposite the enemy. The Russian sappers were used very extensively in fortifying Liao-Yang. As required by the regulations they were, aside from the difficult work falling to them alone, distributed among the works and otherwise very often scattered about as instructors. The regulations of both adversaries resemble each other throughout in this superfluous and pernicious arrangement. The Japanese even go so far as to require of the sappers the digging of cover for the field guns, and only in case of necessity require artillery itself to do it. This is the more surprising, as in another place the training of the artillery in pioneer service is declared to be valuable. The question of intrenching tools can not be the deciding factor here, as the field and mountain artillery carry along 36 large spades, 18 mattocks, 6 crowbars, 12 axes and hatchets and 6 saws. The corresponding numbers for a Russian field battery are: 32 spades, 8 mattocks, 2 crowbars, 24 hatchets and 4 saws. The Russian sappers are drawn on, according to the regulations, for building cover for heavy batteries.

The equipment of an infantry company with intrenching tools is seen from the following table:

	Spades.		Mat-tocks.	Picks.	Axes and hatchets.	Crow-bars.	Cutting bars.
	Large.	Small.					
Russian Company:							
Portable -----		80	---		20	---	
In wagons -----	16	---	3	3	8	1	---
Japanese Company:							
Portable -----	68	---	17	---	8	---	5
The Russian Sapper Company carries:							
Portable -----	100	---	10	20	70	---	---
In wagons -----	40	---	5	5	40	2	---

Against this the Japanese sapper company is to carry a better implement as a portable intrenching tool and, aside from picks, only tools for building bridges.

In the place of the reserve intrenching tools which we have in our divisional bridge train, parts of the field engineer park will probably be assigned to the Russian sapper battalions, while it may be assumed that the ponton trains of the Japanese sapper battalions carry such reserve intrenching tools in packloads.

As there have arisen during the course of the war difficulties which are incomprehensible to us and which the Russian military literature and the new Guide for the Conduct of Detachments of all Arms in Action have cleverly conjured up from the attitude of the leaders, general staff officers and commanders of technical troops, an explanation thereof will not be wanting. Necessity rides over such matters even in Russia. There have been opportunities enough to come to an agreement, and if the war has done nothing else for field fortifications it has brought the certainty that they are entirely indispensable and that the troops understand it, which does not seem to have been the case throughout after 1877-78.

Attention has already been called to the fact that demolitions of civil structures have not been accomplished with especially great effect by either side. Only the demolition of the railroad bridge across the Hungho, by blowing up the piers, was thoroughly prepared and successful. Otherwise the Russians contented themselves at first, when retreating, with carrying off or disabling the rolling stock, destroying stations, telegraph lines and smaller

bridges and, finally, with tearing up the track. The railroad bridge across the Taitzu at Liao-Yang was set on fire during the withdrawal. The destruction of the railroad first became more thorough in rear of Tiehling. However, to want to make up after retreating for what has been neglected is always difficult. Even an undertaking carried out on a large scale, as that of General Mishtchenko in the beginning of January, against Newchwang-Yingkou brought in a technical sense not much more than a single day's results by some cossack patrols which had reached the railroad in rear of the Japanese positions. By the aid of the mounted sappers, attached to the detachment, only the interruption of the railroads to Sinmintun and Tashihehiao-Liao-Yang was effected by blowing up the railroad bed and perhaps some culverts as well as several embankments; longer stretches of telegraph lines were also destroyed. A train with infantry despatched from Tashihehiao was derailed, while returning, by the damage done to the railroad bed.

That nothing more was accomplished on the Japanese side must be wondered at, as the position of the single Russian line of communication contained in itself a challenge to the Japanese to accomplish its destruction for good and all at any price. This is the more peculiar, because the Japanese are said to have found in the Hunghuses valuable allies for operations against the lines of communication, and to have armed them and given them a military organization. All their undertakings were frustrated as a result of the activity of the East Asiatic frontier guards. According to the Service Regulations for the Technical Troops, extensive destruction of railroads and telegraph lines is to be done by railroad and telegraph detachments on orders from the commander of an army.

Data are also lacking as to how the explosives and the equipment of the cavalry and technical troops have stood the test. The attaching of mounted sappers to large bodies of cavalry in the theater of operations in the East was the only possible way of performing technical work of any magnitude, on account of the condition of the roads, as already described.

As regards the explosives of the Japanese, it is here sufficient to say, while referring to Part IX of the *Kriegstechnische Zeitschrift* for 1905, that the quantity of material carried along by the sapper companies is smaller, but that its transportation on horseback is more suitable than is the case with us.

The Russians still cling to guncotton as an explosive, using it in slabs, borehole cartridges and cavalry petards. Their equipment

of explosive and ignition material is not essentially different from what we use. The effect of their guncotton may be somewhat smaller than that of other common kinds of explosives.

The hand-grenades, used by both sides for the assault and for repulsing it, are nothing but explosive charges of the size of one or two cavalry torpedoes, provided with a detonator and a short rubber-covered fuse, in a suitable case (also shrapnel cases which have not burst), which are thrown by hand or from a simple frame.

The technics in the fortress warfare around Port Arthur has been considered incidentally only. What there is of interest from a technical standpoint is the question how it was possible to push the close attack up to the forts engaged; when and how the miner began his work and how the breaching was prepared and actually accomplished. The answer thereto will certainly prove that the sapper and miner will have to seek and find suitable methods for conducting the principal arm into the hostile position. It has been suggested that in fighting against well-fortified field positions a method similar to that of the fight against fortresses is necessary, which will not only bring the artillery, but also the technical troops into action and at the same time bring them recognition.

The more technics has been drawn on for service in war, the more it has promoted the science of war, but has also complicated it. The fundamental principles and teachings of the art have remained the same; their application has, however, become more difficult and demands knowledge and utilization of all technical auxiliary means. We ought not to deny the fact that only well-trained technical troops will guarantee this. A more extended specializing than exists with us can not be advocated on the ground of the experience gained in the war. A sufficient number and a thorough training, together with a careful selection of what is necessary, are, however, indispensable requirements for the advancement of the arm and for the needs of the army.

MOVABLE TOPS FOR FIXED DAMS

BY

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Usually hitherto our fixed dams have been built without any movable parts, though temporary flashboards have often been used. The movable dams, of course, have had fixed parts as foundations, but these have generally been placed low, projecting but little above the river bed, so that they form practically no obstruction during flood stages when the dams are lowered. It is obvious that a combination of the two systems, using a movable top with a fixed dam of less height than would be required for a fixed dam alone, offers some important advantages. If the crest of the dam is lowered several feet during freshets, the flood heights will be diminished to some degree. The lock will require less guard or height of its walls above normal pool in order to avoid submergence for a given discharge. The fall at the dam is reduced, giving less risk of damage to the foundations. Or with a given height of fixed dam a movable top may be added for use during low stages, thus extending the length of navigable pool and reducing the number of locks and dams required.

Movable dams of the usual Chanoine wicket type, operated by maneuvering boats, have the serious disadvantage for a cold climate, that they can not be kept raised in the presence of ice. Thus for several months in the year the pools can not be maintained, and navigation must be subjected to the vicissitudes of open-river conditions at a time when low-water stages may obtain. To guarantee a minimum depth for navigation under such circumstances, a certain height of fixed dam would be required. This would increase flood heights to some degree and require greater guard for the lock walls, but it would also reduce the size of the movable parts and the difficulty of working them. It would, moreover, lessen another difficulty that may give rise to some trouble. The reservoir capacity of the pools formed by the seven movable dams already in service in the Pittsburg District is estimated at about 1,000,000,000 cubic feet.

It is obvious that the filling of a long series of pools after a short "flashy" rise that has forced all the dams down may cause serious disturbance in the flow of the open river below these pools. This trouble would be relieved in so far as the pools are made permanent by the fixed portions of the dams.

The type of movable top to be selected, in case it is decided to use one, may depend somewhat upon the desired height, but for the usual range of from 3 to 6 feet there are a number of designs that are available. It is proposed in this article to refer only to those forms of movable parts that have been used or considered in plans for works in the Pittsburg District. It is hoped that further information may be given by those who have used these or other types elsewhere.

The kinds of movable weirs that have been built in this district are the bear trap, the Chanoine wicket, the Thomas A-frame, and the Chittenden drum. The Poiree needle dam is also used for coffering purposes. Only the drum, however, has been used as a movable top for a fixed dam. Temporary flashboards, consisting of boards placed on edge, one above another, nailed to uprights and supported by iron bars set into the dam, have been regularly used for a number of years during low water at the old dams on the Monongahela River. These are destroyed by floods and may have to be renewed one or more times during a single season. In the process of reconstructing these old works that were bought from the Monongahela Navigation Company new dams have been built at Nos. 2 and 3, and each of these has been furnished with a steel drum movable top having a lift of 3 feet. The first one was installed at Dam No. 2 in September, 1906, and the second at Dam No. 3 in August, 1908. The two are substantially alike, but a few changes of details were introduced in the second one. The accompanying section of Dam No. 3 illustrates the general features of the design.

The dam consists of a concrete superstructure supported on piles and gravel base, protected on upstream side by triple-lap sheet piling and on downstream side by apron crib of timber filled with stone, sheeted with planking on upstream side, and protected in turn by derrick stone along its downstream side. Each drum forming part of the movable top is a long steel box, braced internally, with a section like a sector of a circle, and hinged along its upstream angle. A recess of similar section is formed in the top of the dam to receive the drum when lowered. In the body of the dam is a conduit controlled by valves in the river wall of the lock, in the abut-

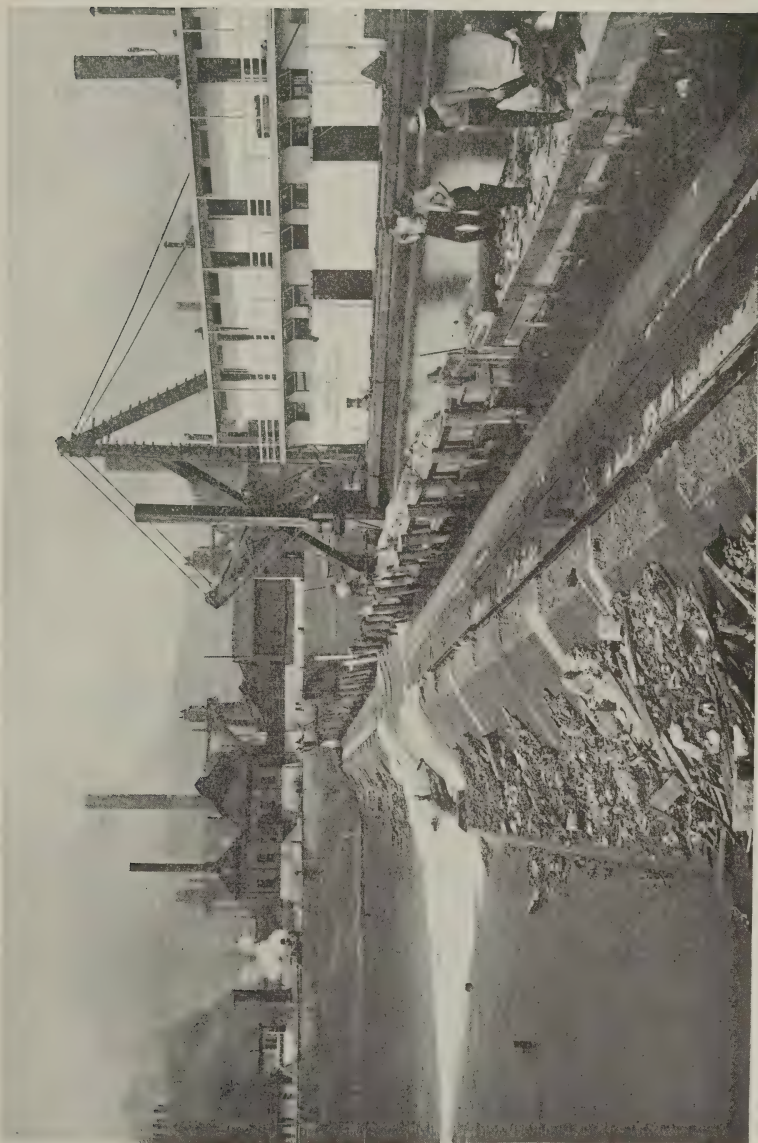


Fig. 2. Part of Dam No. 2, Monongahela River, showing drums lowered.

ment, and in the pier located about the middle of the dam. This conduit is connected with the drum recess by openings, 8 by 10 inches, spaced 3 feet 6 inches, center to center. The drum is provided at its lower edge with a wooden flap to reduce leakage through the clearance space of about 1 inch that is left between the drum and the cylindrical surface of recess. A steel plate covers the gap between the concrete and the drum along the hinge line. The drums have been built in lengths varying from about 40 to 49 feet. They are closed at the ends and provided with wooden sealing strips to reduce leakage between consecutive lengths. The drum is kept from rising too far by stop bars riveted to its under side and projecting sufficiently to engage under the adjustable stop plates that are fastened to the angle iron protecting the downstream edge of the recess. The drums are carefully calked to make the joints airtight under a pressure of 15 pounds. Three-fourth-inch drain holes are provided near the lower edge of the curved plate. At Dam No. 3 a separate pipe line leads to each drum from the compressed air main on the river wall of the lock. The flexible connection with the drum consists of a telescopic joint between two ball-and-socket joints. At Dam No. 2 the connections are of a type that does not give such complete flexibility, and ten of the drums are joined to one air line, eight to another, and only two drums have separate lines.

The drums at Dam No. 2 were installed under rather unfavorable conditions. The work had to be done very hastily so that the system could be tested in time to determine whether it should also be used at Dam No. 3, which was about to be built. After the drums were in place, it was found that they would operate satisfactorily, but they would gradually lose air and take up water and therefore sink below the fully raised position, until they were brought up again by a fresh charge of air. This renewal of the air supply was necessary every few hours. After being in service for some time, the drums were lowered for the winter, and there was no attempt to raise them until the following spring. After the flood season had passed an effort was made to operate the drums, but it was found that the outlet valve in the pier was blocked open by a piece of drift that had somehow become wedged in place. It was necessary to unwater a portion of the dam with flashboards in order to fix the valve, and it was decided to await a lower stage of the river in order to facilitate this work. The season of 1907, however, was characterized by a greater low-water discharge than had occurred for a



Fig. 3. Part of Dam No. 2, Monongahela River, showing drums raised.

number of years, and so there was no favorable opportunity that year to do the work required in order to remove this obstruction from the valve. For the same reason, of course, there was little need of raising the drums. The work was finally begun, however, as the low-water season of 1908 was approaching. One-half the dam was unwatered at a time. It was then found that a great deal of repair work was necessary, requiring the services of the repair steamer *Slackwater* for about two months. Many of the plates covering the recess along the axis of the drum were gone, their hinge connections with the concrete having failed in one way or another. A few of the compressed-air pipe connections with the drums were also missing, and there were evidences of considerable corrosion by acid in the river, indicating a comparatively short life for such a steel structure in that situation. Probably the most singular feature that developed, however, was the condition of the drums in being more or less filled with mud. In some way, during the eighteen months the drums were down, the mud had accumulated in them to a remarkable extent, in several instances almost completely filling them. The drums were thoroughly cleaned, calked, and painted, and the lost, broken, or worn-out parts were replaced. The cost of the repairs was somewhat over \$4,000, or more than ten times the estimated annual expense of ordinary wooden flashboards.

After these repairs were completed, the performance of the drums was very satisfactory. They were kept up continuously for a number of months without requiring any fresh charges of air. During 1909, also, they operated well, though they did not remain quite so air-tight, and it was necessary to apply the compressed air about once a day to keep them fully raised. The drums at Dam No. 3 were put in service in August, 1908, and remained up the rest of the season without any fresh application of air. In 1909 they did the same, with the exception of two drums which had to have additional air a couple of times a month in order to keep them fully raised.

Prior to the extensive repairs made at Dam No. 2 in 1908 new Dam No. 5 had been designed, and the plan included a drum movable top. The discouraging experience at Dam No. 2, however, while the repairs were in progress, suggested the advisability of adopting some less expensive form of movable top for Dam No. 5, and studies were accordingly undertaken with this end in view. Among the various types that seemed more or less applicable there

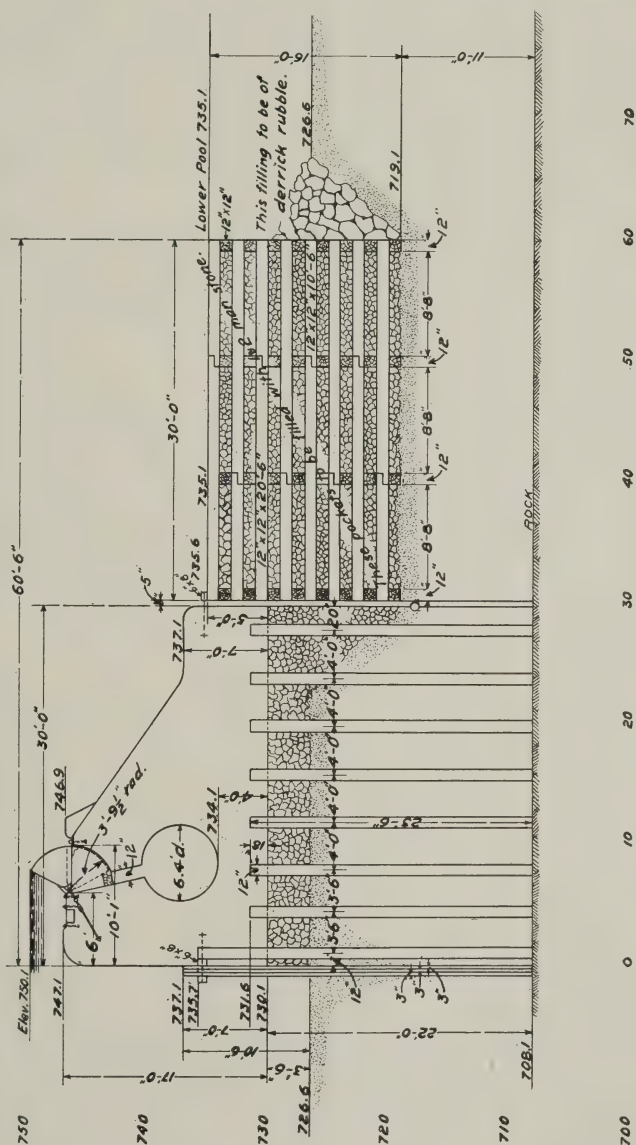


Fig. 4. Showing first design for movable top to Dam No. 5, Monongahela River.

were four that were given more extended consideration than the rest, as being more suitable for this case.

The Chanoine wicket makes quite a satisfactory movable weir under some conditions. The short wickets required in this instance could readily be raised by the lock force, using a small flatboat for the purpose, but, in order to lower the wickets safely in case the water should rise, a tripping bar seemed necessary, and it was considered doubtful whether the full length of the dam, 555 feet, could be effectively controlled in that way.

The Thomas A-frame could apparently be maneuvered from the lock wall, but after working at the plans for some time, it was concluded that this design was somewhat liable to obstruction by drift in the operation of lowering, and failure to lower might cause serious trouble.

Assistant Engineer T. P. Roberts suggested a plain shutter, or wicket, hinged at its upstream edge, to be held in a raised position by a wire that would break under a sufficient head and allow the wicket to fall flat upon the top of the dam, where it would be protected from ice and drift by the sill or mass of concrete to which it is hinged. The uncertainty about the falling of this wicket and the greater power required to raise it led to its rejection in favor of the type adopted, but it is considered worthy of trial in case the latter does not prove satisfactory.

The form adopted for trial is an automatic drop shutter, which may be termed the Betwa wicket, as it has been successfully used on the Betwa Dam, India. (See *Engineering News*, June 4, 1903.) The movable crest of the Betwa Dam is 3,600 feet long and consists of 300 shutters, each about 12 feet long and 6 feet high. For Dam No. 5 the wickets are to have the same length, but are only 3 feet 8 inches high. Each wicket is held in position by two tension bars anchored to the concrete crest of dam and attached to the upstream side of the wicket at about the height of the center of pressure for a depth of 3 feet of water above the top of the wicket. As the water rises the center of pressure moves upward, and the wicket is thus tripped automatically. As the frictional resistance to tripping offered by the lower edge of the wicket sliding on the concrete is unknown, it is proposed to make the tension bars in two pieces, joined by sleeve nuts so that their length can be adjusted to produce the desired result. It is realized that ice and drift may cause trouble with this type of weir, but it is thought to be sufficiently promising to warrant a trial.

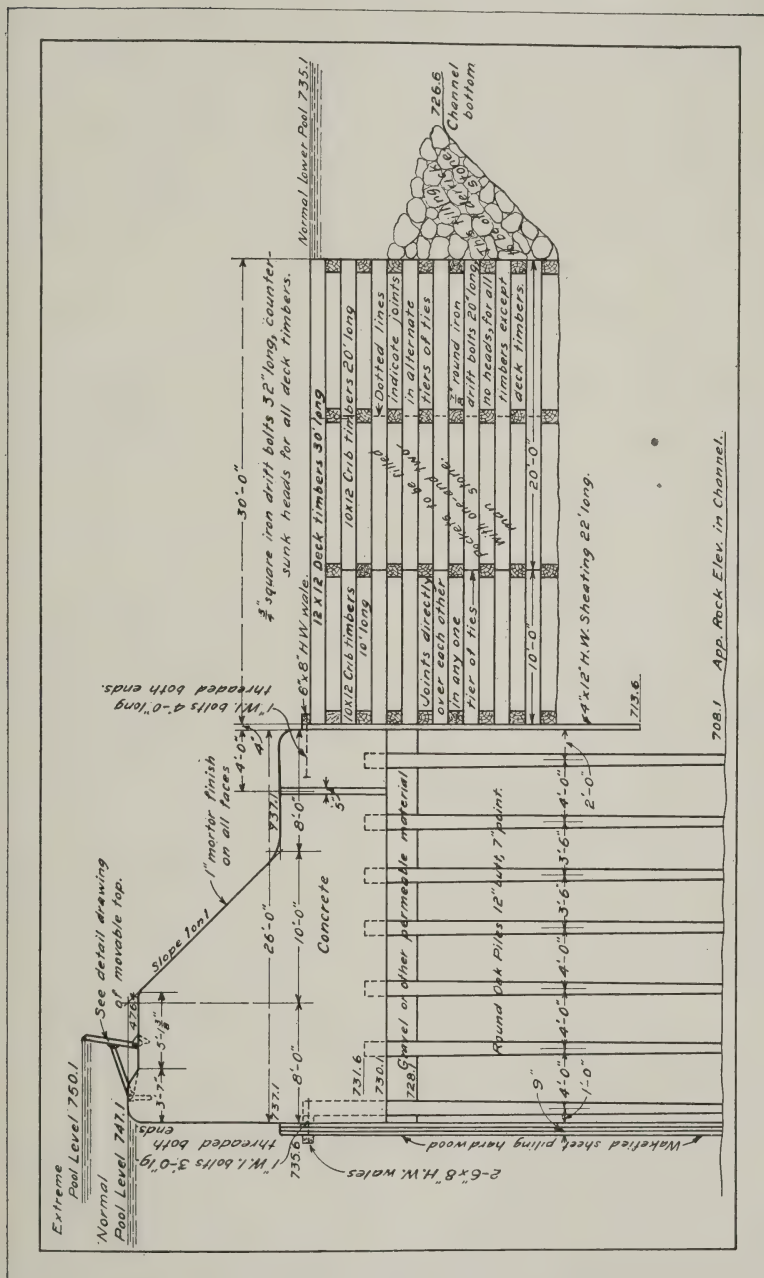


Fig. 5. Showing modified design for movable top to Dam No. 5, Monongahela River.

The accompanying drawings show sections of Dam No. 5 as now designed for this movable wicket top, and also, for comparison, as first designed with the drum weir. The estimated costs per linear foot are about \$8 and \$24, respectively, for the two tops alone. The movable drum top also requires a more expensive section for the fixed dam and a larger power plant for the lock and dam in order to supply the compressed air for operating the drums.

Comparative Costs of Dredging

As showing how much more economically ship channels can be dredged by a large, modern-type dredge, than by a small dredge of old type, the following comparison of the work of the old type Gedney and the new type Raritan in the Main Ship Channel, N. J. Harbor, will be of interest.

In the two years ending June 30, 1909, the Gedney took out 282,831 cubic yards at a cost of \$51,816.99, representing a unit cost of 18.3 cents per cubic yard. In January, 1910, the dredge Raritan was employed a part of her time on the Main Ship Channel, dredging there only by daylight, as the channel is not suitably buoyed for night work. The nights were all spent on the Ambrose Channel. The actual time of dredging in the Main Ship Channel was 229 hours 35 minutes, and in the Ambrose Channel, 196 hours and 5 minutes. The estimated cost of operation for the month was \$8,000, of which \$3,685 is allotted to the Ambrose Channel, and \$4,315 to the Main Ship Channel; the amount dredged from the latter was 80,110 cu. yds., representing a unit cost of only 5.39 cents per cu. yd.

If the Raritan had dredged only by daylight, as the Gedney habitually did, and had laid up at night, and all the expense of the month had been charged against the Main Ship Channel, the cost per cubic yard would have been approximately ten cents, or 45 per cent less than the average unit cost for two years' work of the Gedney. The above, though representing only the field cost, may be taken as a fair estimate of the relative efficiency of the two types of dredges for work of that class.—*From a report of Col. S. W. Roessler, Corps of Engineers, to the Chief of Engineers, U. S. A.*

THE GRADE OF WAGON ROADS

BY

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Corps of Engineers

The experience of the writer in the location of wagon roads has led him to believe that some of the principles laid down in text-books on the subject, particularly those of early date but still considered standard, are misleading. This is particularly true in regard to the question of grade. As the duty of locating and constructing roads is likely to fall to the younger officers of the Corps of Engineers at any time, the results of his observations and investigations may be of interest.

It is to be particularly emphasized, in the beginning, that no uniform requirements can be formulated to cover all cases. The conditions affecting the construction and use of a road are so various, including as they do the amount of funds available, the prospective traffic, the proposed surface, the nature of the country to be traversed, and even the climate, that no set rules for its location are of universal application. The choice of the most advantageous grades must always be a matter of judgment, and the selection of the most advantageous line a matter of skill and experience.

The amount of funds, or, as in the case of roads constructed during military operations, the amount of labor and time available, is frequently the determining factor in the selection of the grade. To be sure, when a macadamized or otherwise artificially surfaced road is to be constructed through ordinary country, the cost of constructing the road bed to moderate grades is usually such a comparatively small portion of the total cost that this phase of the situation is not so prominent. It is prominent, however, when on the one hand expensive land must be acquired, or heavy damages paid to secure a line on which a road with a low grade can be constructed; and on the other hand, when a considerable length of ordinary earth road is to be constructed with limited resources. In the latter case, by using heavy grades, it is usually possible to greatly decrease the quantity of earthwork necessary for construc-

tion, and frequently possible to avoid rock cliffs and ledges, swamps and marshes, or ground with so steep a slope that expensive retaining walls, or other costly means, are required to sustain the road on the located line; and thus bring the cost of construction within the available means. A thorough understanding of the resources in the way of funds or labor is therefore essential before the grades can be determined upon.

In civil operations final economy may render it advisable to defer construction, if funds are limited, or to construct the road on a better location as far as available funds permit, leaving the future to provide means for its completion. It must always be borne in mind, however, that the development of the country resulting from the use of a completed road, even with heavy grades, may justify its construction on the cheaper location. Its abandonment after the resources of the country have so far increased as to render possible the construction of a new road on a better location can not be regarded as evidence of error in the original location, popular views to the contrary notwithstanding.

In military operations the completion of the road with the available resources, within the required time, is evidently of such paramount importance that everything must give way to it.

In addition to the absolute requirement that the cost be within resources available, there is, of course, the economic requirement that it be commensurate with the benefits attained. In this respect, however, it would seem that in regions where a continued and increasing traffic is to be expected, a very considerable outlay is justified in order that a location that will never need to be abandoned may be secured.

After the question of available funds, the important factors in determining what grades are advantageous and what allowable are the proposed road surface and the character of the prospective traffic. While, to a certain extent, it is true that roads are built for all kinds of traffic that may come upon them, yet a little consideration will show that the case will frequently arise where a particular class of traffic should be given principal consideration. Pioneer roads, as well as most of those constructed in settled countries, are intended principally for hauling freight, but occasionally roads are constructed mainly for stage travel, and frequently highways are built, actually if not nominally, for fast pleasure vehicles. The three have by no means the same requirements as to grade.

Taking first the roads intended principally for hauling freight,

we must observe the close relationship existing between the character of the road surface and the desirable grade. This feature is indeed elaborated in all treatises on roads, but as the data to be used in the investigation of advantageous and permissible grades is developed in its discussion, the consideration of this phase of the subject may not be out of place.

The resistance of a wagon may be divided into the tractive resistance and the grade resistance. The tractive resistance, or resistance on the level, depends upon the construction of the axles, diameter of wheels, width of tires, etc., all of which are determined by the character of the wagon; to a small degree on the speed; to a great degree on the road surface; and, it is hardly necessary to say, almost directly on the load. As experience has, however, evolved practically standard wagons, best suited to meet the tractive resistance on ordinary road surfaces, no further discussion is pertinent on those elements of the tractive resistance due to the wagon. By considering only ordinary speeds, of from 2 to 4 miles per hour, we may eliminate the question of speed. There remain the factors of road surface and weight of load. As the tractive resistance varies almost directly with the load, we may state, in Table I, the resistance, in pounds per ton of gross load, of ordinary wagons, when moving at a walking gait, on the various road surfaces. This table has been compiled from the results of the many experiments made from the time of Morin to the present date. As will be noticed, the values have a very wide range, as is to be expected in view of the varying character of the pavements in each class. The writer has ventured to insert the resistance of sleds on snow, as estimated from the performance of such vehicles.

TABLE I. *Tractive resistance on road surfaces.*

Surface.	Resistance, pounds per ton.		Angle of re- pose.
	Range.	Repre- senta- tive.	
Cars on steel tracks.....	5-20	15	<i>Per ct.</i> 0¾
Pavements: Asphalt, stone, brick, plank	20-50	30	1½
Sleds on snow	20-100	30	1½
Macadam	20-100	60	3
Gravel	50-150	80	4
Earth roads:			
Ordinary	50-200	100	5
Poor	150-300	200	10
Bad	200-500	400	20

The "angle of repose" for each surface corresponds to the representative tractive resistance given in the second column. It is, we scarcely need remark, the grade down which a wagon would move when once started, without effort and without acquiring velocity. The representative values of the tractive resistance, as given, accord fairly well with the figures cited by various authorities. If anything, they would seem too great. With the smooth, hard surface now secured on a macadam road in first-class repair, the traces of a modern wagon would certainly slacken when descending a less grade than 3 per cent; and an earth road of such a character that the traces would not slacken on a less grade than 5 per cent would be considered poor rather than ordinary. However, as even macadam roads will frequently be found in poor repair, it is undoubtedly safer to consider conditions below the average.

It will be of interest now to calculate how great a load a fair sized team of horses should pull over a perfectly level road, using the coefficients given in Table I. To do so, the power of a horse must be known. As horses vary greatly in weight, and consequently in strength, we may at once set aside any published data which does not take the weight of the horse into consideration. Baker, in his treatise on "Roads and Pavements," page 81 *et seq.*, states that a horse, given reasonably good footing, can exert a pull equal to one-tenth his weight, at a speed of $2\frac{1}{2}$ miles per hour, for ten hours per day, six days in the week, and keep in good condition. Trautwine gives 100 pounds for a 1,000-pound horse. Other authorities give slightly higher values.* It is to be particularly noted, however, that this pull is for all day, day in and day out. Most text-books state that for short periods a horse can pull twice as much, or one-fifth his weight. Although the inference might be drawn that by "short periods" is intended a matter of minutes, yet a little reflection will show that it is, in fact, a matter of hours. Trautwine, in fact, gives it as five hours per day, and the experience of the writer has led him to believe that this estimate is nearly correct. For very short periods, of ten minutes or so, there is no doubt that a well-trained draft horse can exert a pull equal to nearly one-half his weight.† In calculating the power of a team, however, a reduction must be made for interference, as few teams pull perfectly together. This reduction has been taken as 20 per cent, which may be

*See *Annales des Ponts et Chaussées*, 1871, I, p. 439, and 1879, I, p. 364.

†Gillette: *Economics of Road Construction*, 1906, p. 13.

thought excessive, but which the writer regards as representative.

Assuming a team of four fair-sized horses, weighing 1,250 pounds each, and a wagon, with driver, etc., weighing one-fourth of the gross load, with 1,500 pounds as a minimum, we may construct Table II, showing the net loads that can be drawn on a level road, the horses pulling one-tenth their weight, and the pull being reduced 20 per cent on account of interference.

TABLE II. *Net loads of four-horse team on level.*

	Tractive resist- ance.	Net Load.
	<i>Pounds per ton.</i>	<i>Tons.</i>
Cars on steel rails -----	15	20.0
Wagons on pavement -----	30	10.0
Wagons on macadam -----	60	5.0
Wagons on gravel road -----	80	3.7
Wagons on ordinary earth road -----	100	3.0
Wagons on poor earth road -----	200	1.3
Wagons on bad earth road -----	400	0.3

At first glance these figures might appear somewhat high, but it must be recollected that four-horse teams are not usually employed on first-class roads having low grades, except when unusual loads, such as heavy castings, are to be transported. The figures given for the better surfaces are indeed in excess of the capacity of an ordinary wagon.

We have next to compare the tractive resistance with the grade resistance. The grade resistance is, neglecting certain unimportant refinements, 20 pounds per ton of gross load for each per cent of grade. But as, in ascending a grade, the horses must raise themselves as well as the wagon, the weight of the horses must be taken into account in considering the combined effect of grade and tractive resistance. A formula for the net load that can be hauled is easily derived.

Let L be the net load, in pounds.

W be the weight of the wagon, etc., in pounds.

H be the weight of the horse, in pounds.

n , the fraction of their weight that the horses can pull.

k , a coefficient of reduction, to cover interference, etc.

t , the tractive resistance, in pounds, per ton.

g , the grade, in per cent.

r , the angle of repose, in per cent.

Then the pull that the horses exert on the grade is:

$$\left(nH - \frac{Hg}{100}\right)k$$

or,

$$\frac{Hk}{100} (100n - g)$$

and the load that can be hauled is:

$$\begin{aligned} L &= 2,000 \times \frac{Hk}{100} \times \frac{(100n - g)}{t + 20g} - W \\ &= 20 Hk \frac{100n - g}{t + 20g} - W \quad (1) \end{aligned}$$

or, otherwise, since:

$$r = \frac{t}{20}$$

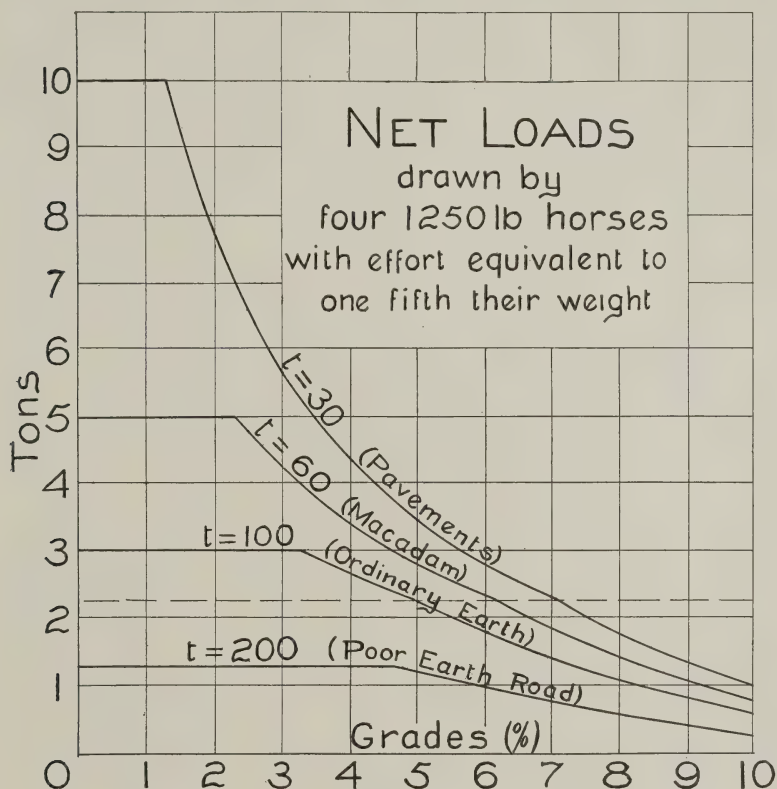
$$L = Hk \frac{100n - g}{r + g} - W.$$

If now we should calculate the net loads that can be hauled on the various grades and road surfaces, on the assumption that the horses pulled the same proportion of their weight as on a level, we would obtain absurd results. We would find, for example, that our team of four 1,250-pound horses, that could haul a net load of 5 tons on the level, macadam road, can haul but 1,000 pounds in a 1,500-pound wagon on a 5-per-cent grade. Everyone with the least experience in such matters knows that such a team can haul several times this load on such a grade.* An error has evidently been made in our assumptions, and this error lies in the assumed pull. If the team were to pull up a continuous 5-per-cent grade, day in and day out, for ten hours a day, there is no doubt but that 1,000 pounds is all they could haul on a macadam road and keep in good condition. But at the end of the first day they would attain an altitude of 6,600 feet! In point of fact, the resistance due to any appreciable grade is never continuous for even an entire day. All that goes up must come down, and there is always a descent to balance the ascent, so that the horses will be but half the time engaged in the up-hill pull. The tables found in many text-books, giving the load

*See Engineering News, Vol. LIII, p. 225.

that can be hauled on grades in terms of the load on the level, can not be regarded as correctly representing the conditions.

To form a comparison of the loads that can be hauled up various grades, we have assumed the same team of four 1,250-pound horses with a dead load of one-fourth of the gross load, or 1,500 pounds as a minimum, and have adopted a pull of one-fifth the weight of the



horses, with a reduction factor of four-fifths for interference. The plotted results are shown in the diagram, the horizontal portions of the curves showing the loads on the level, with a pull equal to one-tenth the weight of the horses.

It is believed that the values shown in the diagram accord fairly well with practice, for long grades up to about 7 per cent, supposing the horses to be sufficiently fed—a supposition that requires considerably more forage than the allowance provided for in the Army Regulations. On grades heavier than 7 per cent teams do, in point

of fact, haul much heavier loads than those shown, adopting a slower speed, and stopping frequently to rest. It is stated by Mr. J. W. Abbott, special agent for the Office of Public Roads, in charge of inquiries in the western division, 1900, that on a properly constructed dry road, four animals, averaging 1,300 pounds each in weight, will haul 6,500 pounds total weight, divided between wagons and contents, up a 12-per-cent grade, at the rate of $1\frac{1}{2}$ miles per hour. The writer has frequently seen approximately this performance on a grade half a mile long, much of which was as high as 12 per cent. Assuming a tractive resistance of 60 pounds per ton, this would require an effort equivalent to nearly one-third the weight of the horses.

As the same effort may be expected from the horses, no matter what the surface may be, provided of course that it is of such a character as to give them good footing, the diagram may be relied on to illustrate at least the relative loads that can be hauled on various surfaces at different grades. A glance shows at once the important general principle that a first-class road surface is of but small benefit unless the grades are moderate; and, conversely, that low grades are of but small benefit unless the surface is good.

Thus, in the particular case that has been chosen as representative, the team can haul 7 tons more over a level, paved road than it can over a level, earth road, while on a 10-per-cent grade it can pull less than half a ton more over the better surface. These principles are, moreover, frequently illustrated in practice. Rarely is a horse tramway seen unless the grade is nearly level. In a new country the earth roads, having generally a very poor surface, will be found to take the steepest grades, if by so doing labor can be saved, better ground obtained, or distance shortened; while the sled roads, having a naturally excellent surface, will go far out of their way to avoid even a moderate grade.

It must of course be understood that while low grades are of small benefit on a road with an inferior surface, yet the combination of a long, stiff grade and a very bad road surface is one over which it is almost impossible to haul anything at all. But it will usually be possible to secure a fairly good surface on a stiff grade, by locating it on suitable ground and attending to its drainage; and a short, stiff grade with a good surface will be cheaper to construct, and easier on the traffic, than a longer, moderate grade with a poor surface.

Turning to more specific investigations, we may first consider the

grade to be regarded as desirable, on any particular class of road, from the standpoint of freight traffic. Of course there is no limit below which it is not desirable to reduce the grade, if other conditions are the same; but a reduction of the grade will ordinarily entail an increase in the length of the road, and in the cost of construction, and there is evidently a limit below which it is inadvisable to reduce the grade, if this reduction requires any appreciable increase in length or in cost. It would seem reasonable to take for this limit, on ascents of considerable length, the grade up which a team can haul the same load as on the level, by exerting an effort equivalent to twice that required on the level. This grade is easily derived from the formula previously deduced.

The load that can be hauled on the level is:

$$L = Hk \frac{100n}{r} - W$$

and on a grade:

$$L = Hk \frac{100n' - g}{r + g} - W.$$

Equating and solving for g , we have:

$$g = r \frac{n' - n}{n + \frac{r}{100}}$$

Or, since we have assumed $n' = 2n$,

$$g = \frac{r}{1 + \frac{r}{100n}}$$

Assuming that $n = 0.10$, as previously discussed, we have the following desirable limits for long grades:

For first-class pavements ($r = 1.5$) 1.3 per cent.

For ordinary macadam ($r = 3$) 2.3 per cent.

For ordinary earth roads ($r = 5$) 3.3 per cent.

For poor earth roads ($r = 10$) 5.0 per cent.

It will be noticed that these values depend chiefly upon the assumed tractive resistance, and that a considerable change in the assumed value of n , the effort to be expected of the horses on the level, does not alter them appreciably. As the values assigned to

the tractive resistance were seen to be somewhat high, it would appear that the desirable limit for long grades should be somewhat lower than those just given. It should also be apparent that the angle of repose can not be taken as the desirable limit to the grade, if this limit is defined as the grade up which the teams can haul, with double the effort, the same load as on the level.

A horse can undoubtedly exert a greater pull than that equivalent to one-fifth his weight for occasional comparatively short distances, without sensibly increasing his fatigue at the close of the day. We find, indeed, in the *Annales des Ponts et Chaussées*, 1871, I, page 451, such effort given as three-tenths of the weight of the horses for distances of one-fourth of a mile. Accepting this figure, and retaining the previously assumed effort of one-tenth the weight of the horse for the average all-day pull, but taking, for safety, somewhat lower figures for the tractive resistance, we have, by a very simple calculation, the following advantageous grades for occasional distances not exceeding one-fourth of a mile:

For first-class pavements ($r=1.5$) 2.6 per cent.

For good macadam ($r=2.5$) 4.0 per cent.

For good earth roads ($r=4.0$) 5.7 per cent.

For poor earth roads ($r=8.0$) 8.8 per cent.

The reliability of these limits depends more on the correctness of the assumptions than does that of those derived for long grades. If, for example, the average pull were taken as 0.15 of the weight of the horse instead of 0.10, and the wagons loaded accordingly, the effort required to pull the load on these grades would be 0.45, a figure undoubtedly verging on the extreme effort of which the horse is capable, and one to be demanded for very short distances only. It is believed, however, that practical experience shows that the figures are such as can be regarded as harmless for *occasional* grades of the length stated, if the road be reasonably straight. The latter point is, however, essential, for on sharp turns the pull of the wheel horses only is available, while on the grades just set forth the pull of the entire team will be required.

Carrying the same reasoning further, it would appear that for occasional extremely short distances, not much exceeding 100 feet, even heavier grades will not be injurious. For such short distances an effort equivalent to two-fifths of the weight of the horses can probably be safely counted on. On this assumption a very simple calculation shows that the following grades will cause no reduction

to the loads that can be hauled on a level road with the normal effort of one-tenth the weight of the horse.

For first-class pavements ($r=1.5$) 4 per cent.

For good macadam ($r=2.5$) 6 per cent.

For good earth roads ($r=4.0$) 9 per cent.

For poor earth roads ($r=8.0$) 13 per cent.

These grades are to be regarded as quite harmless over such distances, and may be freely introduced to save the heavy earthwork that lower grades would entail when the line crosses a ravine or watercourse, or runs up a steep bank. There are several requirements that such pitches must fulfill, however, if they are not to be objectionable. They must not occur on a long grade, where the energy of the horses would be already sapped. Again, the road must be practically straight, both on the grade and its approaches, as the utmost pull of the entire team will be required. Finally, the road surface must be such as to afford good footing for the horses.

It has appeared preferable to approach the desirable grades by comparing the proportional effort that may be temporarily demanded of the teams with the average all-day pull, rather than by assuming some conventional amount as the full load of a wagon, and some fixed figure for the pull of the team, as is sometimes done. If the volume of freight is sufficient to make freighting a regular business, it will be found, indeed, that the wagons will be loaded to the maximum that the surface and grade permit, without reference to any normal load. In the more usual case, where freighting is a more or less incidental occupation, there may be, to be sure, some normal load, determined by the capacity of the wagons ordinarily used in the country, or such circumstances as a haul through by-roads and fields, but this normal load will vary with the section of the country, the season, etc., and no value of general application can be assigned to it.

The grades so far investigated are those which are desirable, provided that no appreciable increase in the length of the road, or in the cost of its construction, are necessary to secure them. The influence of these two factors may now be considered.

In the vast majority of cases, low grades can be obtained only at the expense of distance. It is ordinarily quite impossible to cut through hills. Either the road must turn around them, or, when this is impossible, as when a continuous range of hills must be crossed, its length must be deliberately increased, in order that

elevation may be attained more gradually. If a low grade be selected for a road, therefore, the teams will require a longer time to deliver their loads, while if a heavy grade be chosen, the loads must be reduced. The question arises as to what grade is the most advantageous.

As the increase in the length of the road corresponding to a decrease in the grade will depend entirely on the topography of the country, and will not generally be the same in any two cases, it is impossible to deduce precise general conclusions. We may, however, consider the particular and extreme case when the length must be increased directly as the grade is decreased, or, in railroad parlance, when the grade must be developed.

The expression for the net load hauled is (Eq. 1, pg. 218):

$$L = 20 Hk \frac{100 n - g}{t + 20 g} - W.$$

We will assume that W , the weight of the wagon, bears a fixed proportion to the net load, L .

Let x be the length of the road.

s , the average speed of the horses, assumed constant.

R , the rate of delivery of the freight.

Then we have, under our assumptions:

$$g = \frac{c}{x}$$

and

$$R = \frac{L}{\frac{x}{s}} = C \frac{100 n g - g^2}{t + 20 g}.$$

The maximum value of R will then be found to correspond to:

$$g = -\frac{t}{20} + \sqrt{\left(\frac{t}{20}\right)^2 + 100 n \left(\frac{t}{20}\right)}$$

If r is the grade, in per cent, of the angle of repose of the given surface (Table I), we have:

$$r = \frac{t}{20}$$

and the grade giving the maximum rate of delivery will then be:

$$g = -r + \sqrt{r^2 + 100 n r}.$$

This expression was derived on the assumption that the weight of the wagon was a fixed proportion of the load. It may be noted, in passing, that if the weight of the wagon be assumed as constant, the maximum rate of delivery will be had when

$$g = \sqrt{\frac{Hk}{Hk + W}}(r^2 + 100nr) - r.$$

Assuming an effort equivalent to one-fifth the weight of the horses, we have then, for the most advantageous developed grades:

For first-class pavements ($r=1\frac{1}{2}$ per cent) 4.2 per cent.

For ordinary macadam ($r=3$ per cent) 5.2 per cent.

For ordinary earth roads ($r=5$ per cent) 6.2 per cent.

For poor earth roads ($r=10$ per cent) 7.3 per cent.

And assuming an effort equivalent to three-tenths the weight of the horses, we have:

For first-class pavements 5.4 per cent.

For ordinary macadam 7.0 per cent.

For ordinary earth roads 8.3 per cent.

For poor earth roads 10.0 per cent.

While any theoretical investigations on a subject in which the conditions are as uncertain and irregular as those of wagon transportation must be accepted with caution, yet it is believed that the results just set forth can be accepted as agreeing with practice. The writer would certainly be opposed to developing a less grade than 6 per cent for an ordinary earth road, and he is as certainly of the opinion that a heavier grade than 8 per cent is disadvantageous. Assuming their correctness, the most advantageous developed grade is seen to depend largely on the effort to be expected from the horses. This will depend on the length of the pull. For developed grades of moderate length, say, up to half a mile, the heavier grades shown would appear to be not only admissible, but advantageous. For longer grades the less figures are undoubtedly preferable.

In the general case, however, the length of the road between the usual points of receipt and delivery of freight will not be increased in the same proportion as the ruling grade is decreased. Under these circumstances the most advantageous grades will, of course, be less than those for directly developed grades. While no exact conclusions can be conveniently deduced, yet, roughly speaking, the examination of typical cases would seem to indicate that within the

limits that have been stated the ruling grades should be increased by 1 per cent, if the total length of the road in any particular case will thereby be decreased by :

30 per cent for a first-class paved road.

25 per cent for an ordinary macadam road.

20 per cent for an ordinary earth road.

Thus a macadam road 6 miles long with a 4-per-cent ruling grade will be more efficient for handling freight than such a road 8 miles long with a 3-per-cent grade.

It is therefore seen that a very considerable increase in length is required to offset a moderate increase in grade, if the road surface is at all good. These conclusions are again confirmed in practice, as anyone will testify who has observed the route taken by freighters when there is a choice of several roads. The writer, at least, has yet to see a case when the teamsters did not take the route that offered the least grades, provided that its surface was good, almost regardless of its length. Practically, it may even be said that, as far as the effect on freight traffic is concerned, the consideration of the increased distance required to secure moderate grades will not usually enter into the question. The cost, and, on earth roads, the matter of suitable soil, are the two factors that usually limit the reduction of the grade.

The limitation to the reduction of the grade on account of the cost of construction has already been touched on. Very frequently this limitation is absolute, without regard to the question of whether a greater expenditure is economically justified. When this latter question arises, it can be solved only by a careful estimate of the prospective traffic, and a comparison of the costs of construction on various routes. Bearing in mind the fact that, in these days of railroads, no very heavy freighting may be permanently expected on a road of any length, it will usually be found that the advantage, from a freight traffic standpoint, of extremely low grades will not justify a very large expenditure on construction. Indeed, broadly speaking, under ordinary conditions of traffic, and in a country with ordinary topography, it seems to be generally regarded that, while lower grades are undoubtedly preferable, the requirements of freight traffic are sufficiently served by a grade of 5 per cent on a macadam road. Pavements require such a considerable sum for their construction that they must be limited principally to city streets, and land values and damages exert an all-controlling influence on their grade, so no such standard can be stated. As for earth

roads which are not expected to develop into macadam roads, no very definite standard would appear to obtain. On such roads the matter of suitable soil is most important, and a section of wet or sandy, level road will be far more deleterious than even a stiff grade, so that a heavier grade is more readily justified than on a road with a better surface. Nevertheless, if a road is intended for a good one of its class, the needs of freight traffic will ordinarily justify the expense necessary to limit the long grades to 6 per cent.

It must be understood that the grades that have just been advanced as standard are by no means absolute. On the one hand, the hauling of freight will be facilitated by the employment of less grades; and on the other hand, fair loads can be hauled up much heavier grades. It has already been pointed out that horses can, for comparatively short periods, exert a much greater effort than one-fifth of their weight. By stopping to rest his team at frequent intervals the teamster can develop an increased effort even on comparatively long grades. Taking this effort as three-tenths of the weight of the horses, we have the following calculated net loads:

	Team of four 1,250-lb. horses.	Team of two 1,000-lb. horses.
<i>On an 8-per-cent grade.</i>		
Over a good pavement ($t=30$)	Tons. 3.5	Tons. 1.7
Over an ordinary macadam ($t=60$)	3.0	1.4
Over an ordinary earth road ($t=100$)	2.6	1.1
Over a poor earth road ($t=200$)	1.7	.6
<i>On a 12-per-cent grade.</i>		
Over a good pavement	1.8	.7
Over an ordinary macadam	1.7	.6
Over an ordinary earth road	1.4	.5
Over a poor earth road	.9	.3
<i>On a 15-per-cent grade.</i>		
Over a good pavement	1.1	.4
Over an ordinary macadam	1.0	.4
Over an ordinary earth road	.8	.3
Over a poor earth road	.5	.2

For the two-horse team the reduction factor is taken as 0.95, and the weight of the wagon as 1,000 pounds.

We may therefore conclude that an 8-per-cent grade is not a serious impediment to the hauling of freight, and that even a 12-per-cent grade is permissible; while a 15-per-cent grade is very highly undesirable, but still possible. It is not to be understood

that these grades are advocated, for they are certainly disadvantageous; but it is thought proper to point out that they can be used, when lack of time or money renders it necessary. In tropical countries they would appear particularly inadvisable, as overexertion is there likely to be fatal to the horse. A very important point, and one that the writer has seen frequently overlooked by inexperienced road locators, is that there should be no excessively sharp turns on these heavy grades, since the pull of every horse in the team will be required on them. The writer believes it essential that no curves of less than 100-foot radius be employed on grades exceeding 8 per cent.

It is obviously important to consider the effect of these grades that have been brought forward on military transportation. Now the load of many of the elements of a military train, such as artillery carriages and the wagons of the bridge equipage, are fixed and unchangeable, and the loads of the others are standardized by regulations and can not, in any event, be changed to suit conditions as freely as is possible in the more deliberate commercial transportation. Any theoretical investigation to show that the standard loads of military wagons can be hauled up grades even exceeding 12 per cent would appear superfluous, for such grades are encountered comparatively frequently on the roads of this country, and the standard loads are those that long experience has shown practicable on the ordinary roads in the United States. In considering military transportation, therefore, we are concerned with the fatigue that the grade inflicts on a team hauling a definite load, rather than with the weight of the load that it is possible to transport.

The standard loads in the United States service are as follows:

	Weight of load	Weight of wagon.	Gross weight.	No. of ani- mals	Gross load per animal.
	<i>Pounds</i>	<i>Pounds.</i>	<i>Pounds.</i>		
Field artillery.....			3,900	6	650
Siege artillery.....			8,000	8	1,000
Ponton wagon.....	2,200	2,900	5,100	6	850
Escort wagon.....	1,500	*3,000 to 2,500	4,500 to 4,000	4	1,125 to 1,000

It will be observed that the gross load is comparable to the weight of the animals in each case. Assuming the weight of the standard draft animal as 1,100 pounds, and, further, that the

*Field Service Regulations, 1905, par. 396.

coefficient for interference of the teams is 0.8, it will be seen that, in the formula,

$$L = Hk \frac{100 \ n - g}{r + g} - W,$$

$L + W$ will not be greater than $1.2 \ H \ k$, so that we may safely put

$$100 \ n = 1.2 \ r + 2.2 \ g.$$

If r be taken as 5, the figure usually assumed for an ordinary earth road, we have on a 5-per-cent grade,

$$n = \frac{17}{100},$$

giving an effort of 190 pounds for a 1,100-pound animal; a figure that is certainly not excessive, particularly as it can not possibly be continued for more than half the time the wagon is on the road. If r be taken as 10, corresponding to a poor earth road, we would have, on a 5-per-cent grade,

$$n = \frac{23}{100},$$

an effort still not excessive, and indeed less than twice that required on a level road with the same surface. It would appear, therefore, that a 5-per-cent grade can not be regarded as harmful from the standpoint of military transportation. Less grades are indeed preferable, if they can be obtained without appreciably increasing the length of the road, as they will save the energy of the draft animals, and tend to keep them in better condition to meet the excessive demands that military exigencies will almost certainly make; but it would appear that this result could be better provided for in other ways, and would not in itself justify a reduction of the grade.

For an 8-per-cent grade, on an ordinary earth road, the value of n becomes 0.24, and on a poor earth road 0.30, requiring, respectively, efforts of 260 pounds and 330 pounds from an 1,100-pound animal. While these efforts might not be excessive for commercial transportation, they are probably unduly fatiguing to the animals in a military train, which are halted and hurried on the road, poorly stabled at night, and insufficiently fed. An 8-per-cent grade would not appear injurious, however, for occasional comparatively short ascents, such as those under a quarter of a mile in length.

For a 12-per-cent grade, on an ordinary earth road, the value of

n becomes 0.32, and on a poor earth road 0.38, giving efforts of 350 pounds and 420 pounds per animal, respectively.

Such efforts, though possible, would undoubtedly be injurious to animals in the indifferent condition of those in a military train, if continued for any appreciable time, particularly as the slow gait, with frequent rests, so necessary to develop the full power of the team, can not usually be permitted.

When the employment of a low grade requires a considerable increase in the length of the road, it does not appear that military transportation would be benefited by its adoption. It seems to be generally considered that up to a certain point the fatigue of a draft animal varies almost directly with the amount of mechanical work done by him. If a considerable elevation is to be surmounted, the work done may be divided into that necessary to elevate the gross weight of the wagon and horses, and that necessary to overcome the tractive resistance on the road traversed. The first is constant, the second will vary directly with the length of the road; hence the total will be least when the length of the road is the least, and the grade consequently the greatest. After a certain point is passed, however, the fatigue increases much more rapidly than the effort exerted, and therefore much more rapidly than the mechanical work done. The law connecting these two quantities is necessarily not a fixed one, and, as far as the writer knows, no attempt has been made to formulate it. The critical point that has been referred to appears to correspond to an effort between 0.20 and 0.30 of the weight of the horse. It would appear positively injurious therefore to develop a less grade than 5 per cent for military transportation; and unless the grades were quite long, say, several miles in length, it would probably be found that military trains would take an 8-per-cent developed grade in preference to a 5-per-cent developed grade.

The provision of level stretches of road on long ascents, to break the continuity of the pull, is advocated by some writers. As far as freight traffic is concerned, however, the horses are in practice rested by occasional stops, and the facilities for resting the teams need only be considered in connection with restarting the wagons. To start a loaded wagon requires a much greater effort than is required to pull it after it has started; and, if the wagon were stopped on a grade up which the utmost effort of the horses was required to haul the load, it could not again be started. But on grades of moderate degree, not greatly exceeding the angle of re-

pose of the surface, there will be, as has been seen, a very considerable reserve power for starting the wagon. On moderate grades, therefore, no matter of what length, level stretches can not be regarded as necessary for freight traffic.

It is not the best practice, however, to lay out long ascents on a perfectly uniform grade, since the road can be better fitted to the ground if the grade is varied from point to point. Such a road must naturally run up a side hill, unless indeed it follows the crest of a spur or the bottom of a valley, in either of which cases its grade will certainly not be uniform. A hillside approximating a plane is very rarely found. It is ordinarily broken by ridges and hollows, scarps and benches. By decreasing the grade on the lower side of a depression, and increasing it on the upper, the road may be straightened, possibly to a very advantageous degree. By modifying the grade, also, it may be possible to place the line on portions of the hillside where the slope is least.

The portions of the line where natural conditions have dictated a decrease in the grade may, as a rule, be counted on, therefore, to furnish resting places for the teams, without their arbitrary provision. Where, however, considerations of cost or of soil force the adoption of long ascents with heavy grades, far beyond those consistent with economical freighting, the locator should be careful to see that there are frequent resting places, each at least 50 feet in length, substantially straight, and nearly level. The heavier the grade the more frequent should these breaks be. Incidentally, it may be pointed out, that in addition to their use as resting places, they will form favorable points to dispose of the water accumulating in the upper ditches or gutters. The writer would suggest that the interval between the breaks in the grade should vary from about 600 feet on an 8-per-cent grade to 200 feet on a 15-per-cent grade.

We have so far considered the effect of the grade on ascending teams. The effect on descending teams is not to be overlooked. It need hardly be stated that if the grade is so moderate that large loads can be hauled by the ascending teams, no real difficulty will be experienced by heavy, slow-moving freight teams descending. It sometimes happens, however, that the bulk of the freight is moved in one direction, when the descending loads will determine the advisable grade. In the paper by Mr. J. W. Abbott, previously referred to, it is stated: "Experience in heavy freighting has shown that wagons can be actually and satisfactorily controlled in all weathers on 12-per-cent grades, but that they can not be so con-

trolled on steeper grades, and that where much heavy freighting has been attempted on steeper grades, it has almost invariably been attended with terrible accidents." This statement accords fully with the writer's observations. It should be noted, however, that it does not apply to very short grades, so located that the team can be straightened out before taking them, and kept straight until the speed has been checked, for a dangerous velocity will not be acquired in such a limited time. Nor does the limitation apply when the condition of the road surface, or adverse grades, are such that only light loads can be hauled. For long descents, however, down which heavy loads are to be taken, 12 per cent is undoubtedly the maximum for safety, and if the road is a mountain road, clinging to precipitous slopes, the attempt to take heavy loads down steeper grades will be perilous in the extreme.

But while a down grade of 12 per cent will not directly decrease the freighting capacity of the road, such are to be avoided when possible at reasonable cost. They are expensive to keep in repair, objectionable from the standpoint of stages and light vehicles, and, theoretically at least, wasteful of energy. The first two points will be taken up later. The third may be illustrated by an example. Suppose that a receiving point for freight, or a pass through which the road must run, is 600 feet above the town where the freight is to be delivered, and approximately 4 miles distant from it. Let us further suppose that it is possible to construct a direct road with a uniform descending grade of 3 per cent, which may be assumed as the angle of repose of the road surface; or another road of the same length dropping to the elevation of the town on a 12-per-cent grade, in something less than a mile, and then running level to the town. Now, to haul a load down the first road would require no energy at all, but to haul it over the second would require a 3-mile pull on the level. Under our assumptions this would require the expenditure of 450 foot-tons for each ton of gross load transported, apparently a formidable figure. But, at commercial rates for mechanical power, this work is worth something less than a cent, although, of course, it is worth considerably more if applicable in animal power. Practically the advantage of the first route would depend on the circumstances of freighting. If the wagons were loaded at the upper point, a two-horse team on the first road might do the work of four on the second, but if this portion of the road was but an incident in a long haul, the effect would be noticed only in the long run, from the condition of the horses that had been pulling equal loads over the two

routes. And if the town were at the foot of the elevation on which the first point lay, there would be absolutely no advantage, from a freight standpoint, in developing the grade below 12 per cent. The waste of energy brought about by steep, descending grades can not, therefore, be regarded as serious.

In many of the older books on road location the "rise and fall" of a road is regarded as a criterion of its efficiency. By "rise and fall" is meant the aggregate elevation gained, and subsequently lost, between the terminals of the section of road under consideration. A rule was even formulated to give the distance a road should be lengthened to eliminate a rise and fall, the usual rule being that the saving of 1 foot in elevation would compensate for an increase of 16 feet in length.* The error in this conception should be apparent when a road 10 miles in length, with undulating grades of 2 per cent and a consequent rise and fall of 500 feet, is compared with a road of the same length, with the same rise and fall concentrated in an ascent and descent, each comprising a mile of 10-per-cent grade. A perfectly level road would undoubtedly be preferred by freighters to even the one first mentioned; for, while the writer has frequently seen in print the statement that teamsters prefer a rolling road to a level one, and while he has heard several stage drivers express such an opinion, he has yet to find a practical freighter who did not prefer as level a road as could be had, as long as its surface was good. But it would certainly be quite unjustifiable to increase the length of the first road, with undulating 2-per-cent grades, by a mile and a half to secure a level road, while a far greater increase in length would be justified, from a freighting standpoint, to reduce the long, 10-per-cent grades of the second. If the grades are kept to the minimum consistent with reasonable length and cost of construction, the rise and fall will be a minimum, but it is not itself a correct indication of the best location, nor can any relation be expressed between rise and fall and distance.

We may conclude the discussion of grades from the standpoint of freight traffic by pointing out that, however desirable it may be to have the grades on a road consistent, this feature need not be carried to extremes. That it is desirable that they be consistent is, of course, obvious. Thus, if on a certain road one long grade of 6 per cent is decided upon, it would not be wise to expend large amounts of money, or to considerably increase the length of the road, to bring the other grades much below 6 per cent. On the other hand,

*Science of Road Making, Herschel, 1869, pages 207-63.

if the volume of freight is considerable, and freighting a regular business, the freighters can, and will, take full advantage of all considerable lengths of low grades, by loading for them and doubling the teams on a heavy grade. Again, under such circumstances it is frequently the custom to haul two wagons with a six-horse team. With this arrangement it is easy to drop off the second wagon at the foot of a heavy grade and return for it after the first has been hauled to the top. However, the road is much more satisfactory if the grades are such that the loads can be hauled straight through.

The grade of a road has so far been considered with reference to the weight of the loads that can be hauled over it. We have now to investigate its effect on the speed with which the road may be traversed, or, more exactly, the time required for a vehicle to go from one of its terminals to the other. To be definite, the matter will be taken up principally from the standpoint of stage travel, this being the variety of traffic most deeply and regularly affected, but the conclusions reached should apply, with proper limitations, to the needs of all the incidental light, fast-moving, horse-drawn vehicles that constitute the great part of the travel over an ordinary country highway.

We may point out, in passing, that even at the present day the cases are not so rare when roads are built to accommodate stage travel; such, for example, as the roads in the national parks, the Benguet road in the Philippines, and some very extensive roads that the writer was connected with in Alaska. Many, if not most, of the great European highways, so frequently pointed out as models, were constructed especially for this purpose, and the grades that the engineers of eighty years ago found most favorable for the stages of that day are still quoted as a guide for the present.

In considering the speed of a horse-drawn vehicle, we are at once confronted with the fact that the horse has three gaits, the gallop, the trot and the walk. His speed at each of them will vary according to his training and condition, the weight he is pulling and the grade of the road, but his slowest trot will be much faster than his fastest walk.

As the grade of the road is increased the speed that the horses can maintain at a trot or gallop is not sensibly decreased until, when a certain grade is reached, these gaits are no longer possible. This critical grade will depend on the load, road surface and the condition of the horses. For stages of the character of those used in the Yellowstone Park, and under the conditions there obtaining, it is

4 per cent.* Byrne gives the same limit.† For the winter stages in Alaska, where a thousand pounds or more of express and mail in addition to nine passengers and driver are drawn by the four horses, and where the horses of each post make daily trips of 20 miles or more, the critical grade is rather under 3 per cent. Under normal conditions, however, 4 per cent would appear a fairly safe figure to assign.

After the critical grade is passed, the speed of the team at a walk is not sensibly reduced until a grade of about 8 per cent is reached. On ascents of considerable length with higher grades, halts must be made from time to time, unless the load is very light, to rest the horses.

The limitation on the higher grades occurs, however, rather from the requirements of the descending teams. For fast travel it is, of course, essential that the teams be able to take an increased gait down hill, and as speed is of equal importance in both directions, the maximum grade will be fixed by this consideration. The grades that can be safely descended at a fast gait depend largely on the nature of the vehicle used.

The stages that played so important a part in the transportation of the travelling public before the days of railroads were not equipped with brakes. These heavy vehicles could not, therefore, be controlled on a descent at the high speed demanded at that time, if the grade much exceeded the angle of repose of the road surface. Drags could be employed, but the time lost in applying and removing the drag was of moment. It, therefore, became most important to limit the grades to a low figure, and for this figure Telford and the engineers of his time took the slope of 1 in 35, or slightly less than 3 per cent.‡

The light vehicles of the present time that are not equipped with brakes can safely descend steeper grades, for the horses have not the weight to hold back, nor is there such necessity for speed. It does not appear to the writer that there should be any danger in descending 5-per-cent grades at a trot in a light vehicle, although some books recommend a lower limit.

Stages and other wagons equipped with brakes can undoubtedly descend 8-per-cent grades at a trot if the road is not excessively narrow or does not have excessively sharp curves. This limit has

*Colonel Chittenden, Report of the Chief of Engineers, 1903, pages 2453-5.

†Highway Construction, 1907, page 478.

‡Parnell, Treatise on Roads, 1833.

been adopted for roads in the Yellowstone National Park.* Steeper grades than 8 per cent can indeed be descended at a trot, and with an expert driver at the reins, frequently are regularly taken at the increased gait. If the descent has any length, however, 12 per cent forms the utmost limit for such a proceeding, and the attempt is rarely made to take a stage down a steeper grade at a faster gait than a walk. There is no doubt that 8 per cent is a much more desirable limit for safety.

A fairly noteworthy instance of the advantage of moderate down grades came to the writer's attention in Alaska. There were two roads leading down from a high saddle to a town; one plunging directly down the crest of a steep spur, with a grade in places exceeding 20 per cent, the other winding down the hill sides on grades of from 6 per cent to 8 per cent. The second was somewhat more than a mile longer than the first. The daily stage almost invariably took the longer road down, saving some twenty minutes over the time required to perilously crawl down the shorter; but, when not heavily loaded, returned up the shorter road, despite its steep grades, with some saving over the time required on the longer.

To sum up the results of these investigations, it would appear that on a road intended principally for stage travel, where freighting is of minor importance, grades up to 4 per cent may be freely employed to save cost, and should be employed to save distance. The grade should be kept to this limit of 4 per cent if considerations of cost permit, even if the distance must be very considerably increased. It would not, however, appear advisable to directly develop this grade, or, in general, to employ it when the length of any particular section could be cut in half by using an 8-per-cent grade; for, assuming the speed of the horses at a walk to be half that at a trot, no time would then be lost in covering the section on the heavier grade, and the horses would be, if anything, in better condition after covering, say, half a mile of 8-per-cent grade at a walk than after a mile of 4-per-cent grade at a trot. Furthermore, when considerations of cost or of distance require the adoption of heavier grades than 4 per cent, no particular effort need be made to reduce them to a lower limit than 8 per cent, but it is very desirable not to exceed the latter limit. A grade of 12 per cent is, however, practicable if conditions make it necessary.

It should be evident that the restrictions just set forth on the grades of stage roads do not apply to very short pitches, which can

*Report of the Chief of Engineers, 1903, pages 2453-5.

be surmounted by a brief effort, and on which descending vehicles will not acquire a dangerous velocity. For such short distances grades of even 12 per cent should not be objectionable, if the road is straight, and if they do not occur too frequently. A succession of such pitches should be avoided, however, as the gait of the team must be broken at each, to the irritation of the driver and passengers, and to the fatigue of the horses.

The relation of the road surface to the most advantageous grade is not as marked in the case of stage roads as in the case of freight roads, the conclusions just reached being applicable to any kind of surface that can be classed as fair. If the surface is so very indifferent that trotting would be difficult on even light grades, there can be no object in employing them. On very primitive stage roads, therefore, such as those that must sometimes be laid out under pioneer conditions, heavy grades, say, up to 12 per cent, may be freely used.

In the investigation of grades from the freighting standpoint it was seen that very short breaks are sufficient to afford the necessary resting places on steep grades. For fast traffic this condition does not hold, for, except on extremely steep grades, the teams are never stopped. To relieve the strain of a long ascent, a very considerable length of road with a low grade is required. It would appear obvious that such level stretches should not be gratuitously inserted on a steep side hill, or where a direct loss of distance would result. It often is possible to make use of favoring benches, however, and so break a long hill into a succession of ascents and nearly level stretches, which will be far easier on stage teams than would be a uniform drag from bottom to top. Such level stretches will also afford the drivers of descending teams a most advantageous relief from the strain of a continued application of the brake.

The expressed preference of some stage drivers for rolling roads rather than level ones has already been mentioned. It is hardly necessary to repeat here the time-honored statement that "the popular theory that a gently undulating road is less fatiguing to horses than a perfectly level one is erroneous, being contradicted by the anatomical structure of the horse." Colonel Chittenden, in a report on the roads in the Yellowstone National Park,* explains the preference as due, not to the superiority of a rolling road in itself, but rather to the fact that on such a road the driver is forced to bring his horses occasionally to a walk, thereby affording them some rest,

*Report of the Chief of Engineers, 1903.

while on a level road he is urged by the impatience of the passengers, as well as by his own desire to make time, to maintain an increased gait. Certainly if two roads were offered, each equally long and with the same surface, one level and the other with moderate undulating grades, the writer could not conceive that the second would be used by stage travel in preference to the first, although it might well be that the horses would keep in better condition on the second, because it would be covered more slowly.

The last variety of travel to be considered, but the first in its insistence on low grades and good surfaces, is that of fast-moving vehicles employed for business or pleasure. From the nature of the case the determination of the proper grades for this traffic can not be approached except in a broad and general way. It would appear, however, that little could be gained by adopting lower grades than about 2 per cent, even in the most extreme case when funds are practically unlimited and the traffic of very great volume. Under ordinary conditions 3 per cent would seem extremely favorable, and 5 per cent by no means excessive. Above the limit of 4 per cent the grade of a road constructed for pleasure travel would be a question of expense, as low a grade being adopted as could be had with the available funds almost without regard to the distance required to attain it. In view of the fact that, as a macadam, or at least a gravel, surface would be regarded as necessary for this class of travel, the funds for construction would ordinarily be considerable, and it would seem that grades heavier than 8 per cent would rarely be advisable.

As in the other cases that have been considered, heavier grades than those just mentioned are quite harmless for short distances, if the road be straight, and if they do not occur on a long inclination where the velocity of a vehicle may already be close to the danger mark. A stiff ascent followed by a descent, such as occurs at an overhead crossing of a railroad, is particularly harmless, since the velocity of a vehicle approaching it in either direction will be checked by the ascent, and the driver will be completely in control for the descent. A 10-per-cent grade would seem quite suitable for such a situation. Under less favorable conditions the grade for short distances, possibly up to 300 feet, can safely be as great as 8 per cent.

The influence of the grade on the cost of maintenance of the road must not be neglected. It is expensive to keep the roadway in repair on very heavy grades, as storm water will usually wash and cut it

badly. The effect of the water is increased by the tearing up of the roads by the braked wagons. The damage depends on the nature of the road surface, the violence of the rains, and the provision that has been made for conducting the water away from the road. Presuming that the latter point has been properly attended to, it is believed that on an 8-per-cent grade little damage will be done to a properly compacted roadbed, unless the rains are in the nature of a tropical downpour. Even in the latter case, if the damage is promptly attended to, no serious harm should result. On grades exceeding 10 per cent road surfaces of loamy earth or gravel are likely to be quite badly washed by even a moderate downpour. For this reason 10 per cent forms a most desirable superior limit to the grade of a road, even when the expected traffic is so unimportant as to justify a higher figure.

To improve the drainage of the surface of the roadway, some authorities prescribe a maximum grade of from $0\frac{1}{2}$ per cent to 1 per cent. On macadam roads such an artifice might not be necessary as the crown of the road could be depended upon to shed all the water coming upon it. On earth and even on gravel roads, however, the unavoidable ruts will prevent the crown from throwing off all the water, and a minimum grade of the amount prescribed, with drains at the sags in the line, would undoubtedly be of great advantage. However, unless the road is traversing a perfectly flat country, the grades will usually exceed this minimum, and in such country its attainment will be somewhat costly. It is well, nevertheless, for a road locator to bear in mind the fact that an absolutely level road is not advantageous.

As all investigations must be subjected to the test of practical experience, a comparison of the grades encountered on highways in this country and abroad with those that have been brought forward in this article will be of interest. Taking first the improved macadam roads built during recent years in the United States, we find that on the State aided macadamized roads of Massachusetts a standard maximum grade of 5 per cent for the principal roads, and 6 per cent for the less important ones.* The secondary roads, not macadamized, are deemed worthy of improvement even when the grade runs as high as 10 per cent or even, in some cases, 12 per cent.† On the State aided macadamized roads of New York the

*W. E. McClintock, Trans. Amer. Soc. Civil Engineers, Vol. LIV, page 155.

†W. E. McClintock, Trans. Amer. Soc. Civil Engineers, Vol. LIV, page 147.

maximum grade is fixed at 6 per cent.¹ On the State aided roads in New Jersey no maximum is set. An examination of the published reports on these roads shows that grades of 5 per cent and 6 per cent are not uncommon, and in a few cases the grade is over 9 per cent.²

These grades are high in comparison with the figures given in various treatises as the standards for European construction. A little investigation shows, however, that while these quoted figures may have been decreed as standard at one time or another, yet they are in fact frequently exceeded. Taking the case of the roads in France, we find Byrne stating, "The maximum grade adopted by the French engineers for macadamized roads is 5 per cent or 1 : 20."³ Baker states: "In France the standard is: on national roads, not exceeding 3 per cent; departmental roads, not exceeding 4 per cent; and on subordinate roads, not exceeding 6 per cent."⁴ Whereas M. G. Forestier, Inspecteur Général des Ponts et Chaussées, states, in an article published in 1905, "On National Roads some grades are still over 6 per cent. * * * In regions comparatively level, grades have been reduced to 30 mm. per m. (3 per cent). In hilly regions they are still as high as 8 mm. (8 per cent)."⁵ A perusal of the articles on highways in the more recent numbers of the *Annales des Ponts et Chaussées* would certainly lead one to infer that no standard grades are in use in France.

The Holyhead road in England is frequently quoted as an example of what grades should be. On this magnificent road the ordinary maximum is 3 1-3 per cent, with one section 4½ per cent, and one very short section 5.9 per cent.⁶ It is to be observed, however, that the road was built, at very heavy cost, expressly for the Irish mail stages, before the advent of railroads. No through freight was ever hauled over the line. Another classic example is the road over the Simplon Pass, constructed by Napoleon. This has grades averaging 4½ per cent on one side and 5.9 per cent on the other. The maximum is 7.7 per cent.

It may thus be seen that there is ample precedent for adopting a heavier grade than 5 per cent on even first-class roads.

To take a few more examples of roads laid out under presumably

¹ Bulletin No. 7, Dept. State Engineer and Surveyor, New York, 1904, page 6.

² Report of Commissioner of Public Roads, 1901, page 109; 1907, page 84.

³ Highway Construction, 1904, page 472.

⁴ Roads and Pavements, 1903, page 62.

⁵ Trans. Amer. Soc. Civil Engineers, Vol. LIV, Part F, page 134.

⁶ Baker, Roads and Pavements, 1903, page 62.

skillful supervision, we may note those constructed by the colonial government in Cape Colony, with grades usually limited to 7 per cent, but with some as high as 14 per cent.* The Benguet road, in the Philippines, has a maximum grade, for short distances, of 9 per cent.† The macadam roads recently constructed in Cuba are understood to have maximum grades of 6 per cent. It is inferred from the statements given in Paul's "Road Construction and Maintenance," page 55, that a ruling grade of 5 per cent is adopted for highways in India.

Finally, for examples of roads with quite heavy grades, we have those constructed by a State commission in Idaho, with long grades as high as 12 per cent.‡ The military road penetrating the island of Mindanao from the north side had very long grades of 10 per cent, and that on the south side even heavier grades. Although comparatively light loads only could be hauled over these roads, yet less grades would have entailed extremely heavy work, and their adoption would have greatly delayed the occupation of the territory. But, indeed, one does not have to go far in the United States to find roads with still heavier grades than these just cited, over which all necessary traffic is carried on, with success, if not with economy.

It is therefore apparent that the maximum grade to be adopted for a road can not be decided upon offhand. But the experience of some years in the supervision of road location has lead the writer to believe that perhaps the adoption of a maximum or ruling grade is a feature to which too much importance may be given. Of course, the locator should have a definite idea of the point at which it will be advantageous to develop the line, and, further, of the grade that is the limit for convenience or safety. Depending on the circumstances, the first may lie between 4 per cent and 8 per cent, and the second between 6 per cent and 12 per cent. But his real concern should be to secure the line of reasonable length, with the *least* grades obtainable at an expenditure consistent with the expected traffic, and within the amount that may be anticipated as available for construction, rather than a line on which the grades are merely within an arbitrary maximum.

*Engineering News, Vol. LVI, page 108.

†Engineering Record, vol. 52, page 702.

‡Engineering News, Vol. LV, page 283.

THE QUEBEC BRIDGE

BY

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August 29, 1907, witnessed the collapse of the almost completed south span of the Quebec Bridge, then in course of construction across the St. Lawrence River, at a point about 6 miles above Quebec.

Even to this day there is a diversity of opinion as to the exact cause of the terrible catastrophe, which not only entailed a great loss of money and time, but of many valuable lives as well.

The bridge, however, as then planned, contemplated a cantilever span 1,800 feet long, the longest in the world, and one involving calculations regarding the strength of material and principles of construction, for which there were no prior data to draw on. This lack of experience, rather than any negligence or incompetency on the part of the builders and supervising engineers, must be held responsible for the disaster, and this seems now to be the general opinion; for an examination of the approaches to the bridge and of the piers of that part of the span which is still intact reveals the great solidity as well as the magnitude of the work as originally designed and constructed.

The greater part of the vast pile of iron and steel now lies at the bottom of the river, from 150 to 250 feet beneath the surface of the water. None of this, of course, will ever be recovered. That part of the débris, however, which fell on the shore or into shallow water will be removed in the near future, so as to leave a clear and ample channel for navigation. The contract for the removal of this wreckage has already been awarded.

The Government of the Dominion, moreover, in order to prevent any similar catastrophe in the future, for months past has gathered the most reliable data for the future construction of the bridge, so that the contractors, who shall finally undertake the construction and completion of the bridge, will be able to obtain the fullest and

most complete data upon which to base their calculations and eventual tenders.

This bridge, when finished, will represent one of the greatest bridge-building enterprises in the world, as well as one of the most costly ones.

During the last six months a reliable American company was



Fig. 1. View along axis of wrecked bridge, from south shore.

employed by the Government to make a thorough examination of the river bottom along the line of the proposed structure, also of the present condition of the piers still standing and to be utilized for the new bridge. This company explored the river bottom from shore to shore, sinking about eighteen holes to a depth of from 90 to 100 feet, using 6-inch, 4½-inch, and 3-inch pipes for that purpose. The work has been a most laborious and thorough one to ascertain

whether the piers still standing remained unhurt by the fall of the bridge and to make sure that the new piers will have a safe foundation. The examination, as now finished, shows that no quicksand will be encountered and that the piers, now standing and to be constructed, will rest upon gravel beds, boulders, clay, and on sand that packs as hard as gravel beds. It also shows that the present piers have not been injured in the least, as not even their surfaces were affected in any manner by the fall of the superstructure. This testing work has cost from \$3.50 to \$5 per foot, owing to the great



Fig. 2. General view of Quebec Bridge site, looking upstream.

depth of the river at this place and because of the tides and the strong river current, which prevented steady work.

The ordinary tide at this distance from the mouth of the river rises to 12 feet, while the highest tide rises to about 19 feet. The incoming tide is gradual, owing to the opposing river current, but the outgoing tide is very swift and strong.

The test work also proved that the construction of the piers has been of the best; in fact, that no better work could have been done, so that the fall of the bridge could not in any manner have been caused by defects in the masonry work.

Those of the old piers which will be utilized for the new structure will be made wider, in conformity with the new plans, which contemplate a wider as well as a stronger bridge. The present anchor

piers will not again be utilized, as new ones will be set back inshore from 75 to 80 feet to equalize the weight of the new span. The main pier on the north side of the river will be set farther into the river about the same distance, and the present south pier will be widened. This will reduce the main span of the bridge from 1,800 feet, as originally designed, to 1,705 feet, leaving it still the longest in the world by about 5 feet, that of the Forth Bridge, in Scotland, being the next longest.

It has not as yet been determined whether a cantilever bridge or a suspension bridge will be built, this being largely a question of cost to the Government. Representative bridge builders of the world will be invited to visit the Government engineering offices at Montreal to inspect the plans prepared for both styles of construction, and to tender their bids accordingly. Sufficient time, probably from two to three months, will be allowed for the examination of these plans, in keeping with the magnitude of the undertaking, and ample time thereafter will be allowed for the submission of tenders. In the meantime there is to be no delay in the preliminary work of clearing away the wreckage, the contract for which has already been awarded to the contractor who built the present piers in so satisfactory a manner.

The estimated cost of the substructure will be in the neighborhood of \$2,500,000, while that of the whole structure will in all probability not be less than \$10,000,000.

It is expected that the bridge will be completed in 1914, so that this great undertaking is likely to be finished about the same time as the Panama Canal, each, in its own way, aiding in the solution of the all-important problem of providing better transportation facilities for the ever-increasing products of both nations.

The Quebec Bridge, when completed, will form the link that is needed to complete another transcontinental line across the Dominion of Canada, and thus will constitute an important step in the development of the great transportation systems of this country.

Joseph Gardner Swift

JOSEPH GARDNER SWIFT (see frontispiece) was born at Nantucket, Mass., December 31, 1783. He was a son of Dr. Foster Swift, United States Army, and was a descendant of Thomas Swift and Hopestill Foster, the first settlers of Dorchester, Mass. In 1800 he was appointed a cadet at the United States Military Academy, from which institution he was the first graduate, graduating October 12, 1802, when he was promoted second lieutenant in the Corps of Engineers. His promotions thereafter were as follows: First lieutenant, June, 1805; captain, October, 1806; major, February 23, 1808; lieutenant-colonel, July 6, 1812; colonel and Chief (Principal) Engineer, July 31, 1812. During his service he was principally engaged in the construction of fortifications on the Atlantic Coast. For a short time in 1812 he was military agent at Fort Johnson. In the War of 1812 he first served in the Carolinas on the staff of Major-General Pinckney. In 1813, as Chief Engineer of the Army, he was engaged in General Wilkinson's campaign on the St. Lawrence, participating in the battle of Chrystler's Field, and subsequently, in 1813 and 1814, he superintended the defense of New York, including Brooklyn and the Heights of Harlem. In February, 1814, he was breveted brigadier-general for meritorious services. After the war, he assumed the direct supervision of the Military Academy, of which he was, ex officio, the Superintendent; and was its Inspector for a short period previous to November 12, 1818, when he resigned from the service. Upon his resignation he was appointed surveyor of the Port of New York, which position he held until 1827. From 1829 until 1845 he was appointed, by President Jackson, to superintend the harbor improvements on the Great Lakes. In addition to this work, in 1830-1831, he constructed the railroad from New Orleans to Lake Ponchatrain, said to be the first road to be laid in America with T-rails. In 1833 he was chief engineer of the New York and Harlem Railway. In 1841 he served on a Peace Commission to the British Provinces. He died July 23, 1863.—*From Johnson's Universal Cyclopedia and Gardner's Dictionary of the United States.*

SELECTED ARTICLES OF ENGINEERING INTEREST

Compiled by Henry E. Haferkorn, Librarian, Engineer School

In the lists of selected articles published the publication is referred to by the number preceding its title in the following list.

The following abbreviations will be used: I, for illustrated; D, for diagrams.

- (1) Annales des Ponts et Chaussées, partie technique; bi-monthly.
- (2) American Machinist; weekly; Thursdays.
- (3) Canadian Engineer; monthly.
- (4) Canadian Society of Engineers, Bulletins; May and December each year.
Proceedings; monthly
- (5) Cassier's Magazine; monthly.
- (6) Cement; bi-monthly.
- (7) Cement Age; monthly.
- (8) Cornell Civil Engineer; monthly.
- (9) Electrical Review; weekly; London.
- (10) Engineer (London); weekly
- (11) Engineering (London); weekly.
- (12) Engineering-Contracting; weekly.
- (13) Engineering Magazine; monthly.
- (14) Engineering News; weekly; Thursdays.
- (15) Engineering Record; weekly; Saturdays.
- (16) De Ingenieur (Hague, Holland); weekly.
- (17) Journal of American Society of Mechanical Engineers.
- (18) Journal of Western Society of Engineers; bi-monthly.
- (19) Journal of Franklin Institute; monthly.
- (20) Journal of Royal United Service Institution (London); monthly.
- (21) Proceedings, American Society of Civil Engineers; monthly.
- (22) Proceedings, Engineer's Club of Philadelphia; monthly.
- (23) Municipal Engineer; monthly.
- (24) Municipal Journal and Engineer; monthly.
- (25) Railway Age and Gazette; weekly; Fridays.
- (26) Revue Générale des Chemins de Fer (Paris); monthly.
- (27) Scientific American; weekly; Saturdays.
- (28) Scientific American Supplement; weekly; Saturdays.
- (29) Transactions, American Society of Civil Engineers.
- (30) Professional Memoirs, Corps of Engineers; quarterly.

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- Long span reinforced-concrete girder bridges. F. W. Scheidenhelm. (14), Jan. 27, 1910. I. D.
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- Arch bridge, Bexar County, Texas. (12), Jan. 26, 1910. D.
- Steel bridges. The Clinton Bridge of the Chicago & North Western. (25), Jan. 14, 1910. I. D.
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Description of the new harbor, wet dock, and graving dock at Avonmouth, Bristol, England. A. D. Swan. (4), Dec. 16, 1909. 7,000 words. I.

Notes upon docks and harbors. Luther Wagoner. (29), v. 62, Mar., 1909. D.

DREDGES.

A large elevator dredge for work in Boston Harbor. (14), Jan. 27, 1910. I.

Modern dredging appliances for waterways. J. A. Seager. (5), Jan., 1910. 3,500 words. I.

DRY DOCKS.

Electrical equipment of Smith's docks, Middlesbrough. (11), Jan. 14, 1910. 1,600 words. I.

EXPLOSIVES.

A new explosives ordinance for the city of Chicago. (14), Jan. 13, 1910.

Testing of explosives for sensitiveness to shock by the Dropphammer method. Dr. H. Kast. (19), Feb., 1910.

FOUNDATIONS.

A composite sand and rock foundation for a tall building. (14), Jan. 6, 1910. D.

HARBORS.

The Chicago harbor. J. M. Ewen. (18), Dec., 1909. 18,000 words.

Construction des ports en plage de sable. (1), v. 6, 1909. 6,000 words.

XIe Congrès International de navigation tenu à Saint Pétersbourg en 1898. (1), v. 6, 1909. 10,000 words. (Summary of the discussion on inland sea-ports, means of access, etc.)

HYDRAULICS.

Dimension of an artificial waterway to carry a known volume. H. L. Abbot. (30), Apr., 1910. D.

HYDRO-ELECTRIC PLANTS.

Hydro-electric development and transmission lines of the Canadian Niagara Poyer Company. A. H. Van Cleve. (29), v. 62, March, 1909. I. D.

HYDROGRAPHIC SURVEYING.

Exploration hydrographique des mers. (1), v. 6, 1909. 3,800 words.

INLAND NAVIGATION.

Inland waterways. Transportation in the U. S. (15), Feb. 5, 1910.

LOCKS AND LOCK GATES.

Large angle valves for the Panama Canal. (2), v. 33, Jan. 27, 1910. I. D.

Methods and cost of constructing a concrete lock and timber crib dam. (12), Jan. 26, 1910.

MAP DRAWING.

Direction marks for maps. A. W. Bedell. (14), Oct. 7, 1909. I.

MATERIALS.

Steel corrosion. Rapid deterioration of steel work from the corrosive action of locomotive gas, McCallie Avenue Bridge, Chattanooga, Tenn. Robt. Hooke, (14), Jan. 20, 1910.

—Strength of materials. Theory of impact and its application to testing materials. H. D. Tiemann. (19), Oct., 1909, and Nov., 1909. I. D.

MILITARY.

Technics in the Russo-Japanese War. Toepfer. (30), Apr., 1910.

MISSISSIPPI RIVER.

The reservoir possibilities of the sources of the Mississippi and tributaries of the Upper Mississippi River with reference to the improvement of navigation. C. W. Durham. (14), Jan. 20, 1910. I.

PAVEMENTS.

Concrete paving at Memphis. J. H. Weatherford. (24), Jan. 5, 1910. I.

Economics of street pavements. S. Whinery. (12), Jan. 12, 1910.

PRESERVATION OF TIMBER.

Tests of creosoted timber. W. B. Gregory. (21), Feb., 1910. I. D.

RESERVOIRS.

Covering of the distributing reservoirs at Reading, Pa. (15), Jan. 22, 1910. D.

Outlet control of the Little Bear Valley reservoir. F. E. Trask. (21), Sept., 1909. I. D.

Progress on the Ashokan reservoir. (15), Jan. 22, 1910. I.

Towns. The water supply system of Cheyenne, Wyoming. (15), Jan. 22, 1910. I.

The water supply of Springfield, Ohio. P. Hansen. (15), Dec. 11, 1909. 4,000 words. I.

RIVER ENGINEERING. (*See also "Inland Navigation."*)

River protection work on the Kansas City Southern Railway near Braden, Oklahoma. J. A. Lahmer. (21), Oct., 1909. D.

Movable tops for fixed dams. H. C. Newcomer. (30), Apr., 1910. I. D.

New lock and dam No. 5, Monongahela River. L. M. Adams. (30), Apr., 1910. I. D.

ROADS.

The grade of wagon roads. G. B. Pillsbury. (30), Apr., 1910. D.

The motor car and the road. L. W. Page. (27), Jan. 15, 1910. I.

Road construction and maintenance in Cumberland County, England. G. J. Bell. (14), Jan. 27, 1910.

STREAM FLOW.

Effect of roughness of bed on depth of water and distribution of velocity. E. C. Murphy. (14), Dec. 30, 1909. 1,000 words.

STREET PAVEMENTS.

Review of Chicago paving practice. W. W. Crosby. (21), Oct., 1909.

TUNNELS.

The Detroit River tunnel. S. Godfrey. (30), Apr., 1910. I.

WATER SUPPLY.

Aqueducts. Cut and cover construction on the Catskill Aqueduct. (15), Jan. 8, 1910. I. D.

The world's biggest water project (N. Y. City). (24), Jan. 19, 1910. I. D.

Artesian. The deep well system of water supply for South Bend, Ind. A. T. Hammond. (14), Jan. 27, 1910. D.

WATER-WHEELS.

Characteristics of modern hydraulic turbines. L. F. Moody and J. C. Parker. (21), Nov., 1909. D.

WATER WORKS.

The water works of Marion, Ind. Elkanah Hulley. (23), Jan., 1910. I.

Editorial Notes

The following extract from G. O. No. 4, W. D., 1909, will, it is thought, be of interest to readers of the MEMOIRS as giving in a few words the method recently adopted to acquaint young officers, just entering the Corps of Engineers, with the scope of the work now in progress and to educate them along the lines covered by the various duties of the Corps.

* * * * *

Graduates assigned to the Corps of Engineers will be ordered on the expiration of their graduation leave to report for instruction to Engineer officers in charge of selected Engineer districts, where they will have an opportunity to study the theory and practice of engineering as applied to various important construction works of the Corps. This assignment will be so arranged that each young officer, during his first year of service, will have experience on the Panama Canal, on breakwater or jetty work in connection with harbor improvements, on river improvement, including canalization and movable-dam construction, and on rock excavation under water, dredging, and similar work. During this period these officers will be required by the district Engineer officers to make a thorough study of the works in progress, and to take notes on what they see and do. The last two weeks at each station will be devoted to writing a descriptive memoir upon the works observed, which shall include a comparison of the theory and practice of the work under observation. This memoir will be sent through the immediate commanding officer, who will indorse thereon such remarks as may be pertinent, to the Chief of Engineers, for submission to the Engineer School. If the memoirs are satisfactory to the School Board the author will be given a corresponding credit in the School course.

The second year after graduation will be spent at the Engineer School at Washington Barracks, where the student officer will take the prescribed course in civil engineering, light-house construction, mechanical and electrical engineering, seacoast defenses and permanent fortifications, including land defenses of important harbors. This course will embrace such theoretical and practical instruction as is necessary to fit the officers for their duties as constructing engineers on the works under the charge of the Corps.

Upon the completion of the course at Washington Barracks, the young officers will be assigned to civil or military duty for several years as assistants to older officers. Assignments will be so arranged that each officer will serve with Engineer troops for at least four years before attaining the rank of captain. At least one year of this period will be spent at Fort Leavenworth, Kans., where the student officers will be separated from direct service with Engineer troops and will take the course at the Engineer School of the Line. During this

period of instruction the junior officers will be brought into immediate contact with other troops of the line in order that they may be fully fitted to perform the duties of Engineer officers with the mobile army.

* * * * *

To show that the young officers take advantage of the exceptional opportunities offered to them, it is proposed to print from time to time reports or memoirs submitted in accordance with the foregoing order or extracts from the same. The origin of these reports or extracts will be shown with each article. The memoir on the Detroit River tunnel in the present number, by Second Lieut. Stuart C. Godfrey, is the first of such articles to be published.

The recent report of Prof. Willis L. Moore, LL. D., Sc. D., Chief of the United States Weather Bureau, on *The Influence of Forests on Climate and on Floods*, makes an interesting addition to the literature on the subject of forestry and its effects upon run-off and stream flow. In addition to this subject, it takes up another phase of the question heretofore but little touched upon in the discussion; *i. e.*, the effect of Forests on Climate. This report was made to the House Committee on Agriculture and is both scientific and scholarly. The results of long and careful investigations are submitted and discussed, and the resulting conclusions of the writer seem logically drawn. A few excerpts from the report, and Professor Moore's conclusions follow for those who have not seen the full report:

* * * Whatever marked climatic changes take place (they) are essentially universal and not local.

Prof. William J. Humphreys, Ph. D., Johns Hopkins, professor of meteorological physics, United States Weather Bureau, says:

"These universal slow climatic changes that for thousands of years have been modifying the glaciers and changing the inland seas might very well have led to extensive forest destruction; but that it itself was (they were?) the effect and the destruction of the trees the cause seems most unlikely."

DESICCATION IN ASIA

In this connection I would refer to the opinion of Mr. Ellsworth Huntington, B. A. of Beloit and M. A. of Harvard: * * * "The Lop basin contains abundant evidences of climatic changes, and has been discussed in detail by the writer in 'The Pulse of Asia.' Throughout the basin the amount of vegetation has greatly decreased in recent times without the intervention of man. On the lower slopes of the Kuenlun Mountains the dissected condition of numerous deposits of loess shows that a cover of grass prevailed at no remote date, but has now disappeared. In the zone of vegetation plants of all kinds show signs of a process of drying up which has been in progress for centuries. Tamarisk

bushes stand upon mounds from 5 to 60 feet high, a sure sign of the lowering of the level of ground water; poplar forests which once extended for scores of miles now form wastes of branchless dead trunks like gaunt gray skeletons; and beds of dead reeds cover hundreds of square miles. It has often been asserted that the destruction of forests has been the cause of the diminution of rainfall. In the Lop basin the opposite appears to be the case; the supply of water has diminished, and therefore the forests have died. Rainfall unquestionably controls forestation, but neither in the Lop basin nor in other parts of central and western Asia is there any good evidence that forests have an appreciable effect upon rainfall."

* * * * *

The fact that dead forests stand long after the streams have receded seems to prove that they are the last to disappear rather than the first, and therefore that their removal did not precede the drought but rather that the forests ceased to exist when the rainfall became deficient.

* * * * *

With regard to the effects of forests on rainfall, I quote the following from recent writings of Prof. Cleveland Abbe, who is senior professor of the Weather Bureau and a member of the National Academy of Science. He says: "It is a pity that the errors of past centuries should still continue to be disseminated long after scientific research has overthrown them. It is easy to start false theories and to believe them, because they are generally simple and plausible, but long years of work are necessary before we get at the secrets of nature. In this day and generation, the idea that forests either increase or diminish the quantity of rain that falls from the clouds is not worthy to be entertained by rational, intelligent men."

* * * * *

In New England, where deforestation began early in our history and has been extensive, the mean of the fluctuations in the rain curve is a steady rise since 1836 up to few years ago, and in the Ohio Valley, where the forest area has been greatly diminished, there is no decrease of rainfall shown by the average of the fluctuations of the curve. These facts are important and can not be successfully disputed.

* * * * *

CONCLUSIONS

(1) Any marked climatic changes that may have taken place are of wide extent and not local, are appreciable only when measured in geologic periods, and evidence is strong that the cutting away of the forests has had nothing to do with the creating or the augmenting of droughts in any part of the world.

(2) Precipitation controls forestation, but forestation has little or no effect upon precipitation.

(3) Any local modification of temperature and humidity caused by the presence or absence of forest covering, the buildings of villages and cities, etc., could not extend upward more than a few hundred feet, and in this stratum of air saturation rarely occurs, even during rainfall, whereas precipitation is the result of conditions that exist at such altitudes as not to be controlled or affected by the small thermal irregularities of the surface air.

(4) During the period of accurate observations, the amount of precipitation has not increased or decreased to an extent worthy of consideration.

(5) Floods are caused by excessive precipitation, and the source of the precipitation over the central and eastern portions of the United States is the vapor borne by the warm southerly winds from the Gulf of Mexico and the adjacent ocean into the interior of the country, but little from the Pacific Ocean crossing the Rocky Mountains.

(6) Compared with the total area of a given watershed, that of the headwaters is usually small and, except locally in mountain streams, their run-off would not be sufficient to cause floods, even if deforestation allowed a greater and quicker run-off. Granting for the sake of argument that deforestation might be responsible for general floods over a watershed, it would be necessary, in order to prevent them, to reforest the lower levels with their vastly greater areas, an impossibility unless valuable agricultural lands are to be abandoned as food-producing areas.

(7) The run-off of our rivers is not materially affected by any other factor than the precipitation.

(8) The high waters are not higher, and the low waters are not lower than formerly. In fact, there appears to be a tendency in late years toward a slightly better low-water in summer.

(9) Floods are not of greater frequency and longer duration than formerly.

The Formation of a Brigade of Fortress Engineers in the Russian Army

There has just been formed at Vladivostock, by an order of November 5 (18), 1909, a brigade of fortress engineers which is made up as follows:

- One battalion (4 companies) of sappers;
- One battalion (4 companies) of miners;
- One telegraph company;
- One aeronautic company;
- One wireless telegraph detachment;
- One carrier pigeon detachment.

These units already existed at Vladivostock, although they were not combined in one command.—*From Revue Militaire des Armees Etrangères, Janvier, 1910.*

Errata

Last line, page 167, read *Janvier*, not *Janiver*. Thirteenth line from bottom, page 173, read 2 of 4, not 2 to 4.



PROFESSIONAL MEMOIRS

Corps of Engineers, United States Army, and Engineer Department at Large

Published Quarterly at the Engineer School, Washington Barracks, D. C., by the School Board. NOTE: Authors alone are responsible for statements made and opinions expressed in their respective articles.

VOL. II.

JULY-SEPTEMBER, 1910.

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Subscriptions, \$4.00 per year, in advance; single copies, \$1.00. Advertising rates on application. Address all communications to PROFESSIONAL MEMOIRS, Washington Barracks, D. C.



WALKER KEITH ARMISTEAD
CORPS OF ENGINEERS
CHIEF ENGINEER, UNITED STATES ARMY
1818-1821
BORN 1780—DIED 1845

NOTES ON ROAD BUILDING IN CUBA

BY

LIEUT. COL. MASON M. PATRICK

Corps of Engineers

In April, 1907, about six months after the beginning of the last American intervention in Cuba, the Provisional Governor decided to devote considerable sums of money to the construction of a number of good roads on the island. There were many excellent reasons for undertaking such work. During the whole time Cuba had been under Spanish dominion, and during the time it had been in the hands of the Cubans, but 610 kilometers (about 380 miles) of improved roads had been built on the island, the area of which is 41,000 square miles; the unimproved roads hardly deserved the name; in the low country many of them were veritable quagmires in wet weather, and so full of ruts and mud holes in dry weather as to be frequently impassable by ordinary wheeled transportation; in the hilly sections they were mere trails, steep, often rocky, and scarcely passable for lightly loaded pack animals; all transportation was exceedingly costly and very slow. Off the improved roads all transportation was by pack train and by "carretas" (two-wheeled carts, wheels about 7 feet in diameter with tires only about 2½ inches wide, drawn by from four to sixteen bulls). It was no uncommon sight to see these "carretas" mired in mud holes to their axles. When loaded, they rarely made more than about 20 kilometers per day. The hardship that these conditions imposed upon isolated farmers and communities can be imagined easily; the military disadvantages of such a lack of practicable roads is equally apparent.

Economic considerations and matters of policy also had their influence; many laborers were idle; there was beginning to be some suffering, and consequent unrest; the building of roads would give employment to local labor and probably relieve the situation, which might otherwise grow menacing.

During the intervention, in addition to repairs made to many kilometers of existing roads, the construction of entirely new roads,

aggregating about 750 kilometers in length, was undertaken, and most of these new roads were entirely completed, or well advanced toward completion, when the intervention ended on the 1st of April, 1909.

The work of building these new roads was entrusted to the Department of Public Works, but this department did not have under its control, at that time, a sufficient force of trained employees to permit the entire road building program to be undertaken; hence the Provisional Governor sought the aid of the Engineer troops with the Army of Cuban Pacification.

By orders from the headquarters of that army, the writer was directed to assume charge of the construction of four certain roads in the Province of Pinar del Rio. Upon his recommendation an officer of the Second Battalion of Engineers was placed in local charge of each road, and the writer was further given authority to detail such enlisted men as might be necessary for service on the different roads and to change them from time to time as the exigencies of the service might demand.

The multifarious duties devolving upon the battalion, and orders from Washington affecting both officers and men, made it necessary to change the personnel on each of the roads many times. Furthermore, the experience to be gained on this work was valuable, and an effort was made to permit as many of the officers and men as possible to benefit by it.

Right here it is desired to place on record the fact that this service was most exacting and arduous, and that the work done by all the officers and men of the battalion was performed faithfully and well, and often under most trying conditions. The four roads, whose construction was placed under the supervision of the writer, are described at some length below. All were macadam, or of Telford-Macadam, the width of metal 5 meters, and the maximum grade 6 per cent.

ROAD FROM PINAR DEL RIO TO VINALES

Length, 26 kilometers. This road ran almost due north from the town of Pinar del Rio, about 170 kilometers west of Havana, and for about 11 kilometers it passed over a gently rolling country; then for some 13 kilometers it wound over the ridge, or, rather, series of ridges, to the beautiful valley of Viñales, into which it descended along the hillside, with the maximum grade for about 2 kilometers.

Just where the road begins to descend into the valley of Viñales the view is one of the finest in Cuba. Some 150 meters below lies the fertile valley, about 1 kilometer wide and some 3 or 4 kilometers long east and west. Here and there are thatched native houses or tobacco barns, groves of stately palms, little streamlets bordered with thick growths of bushes, while the cultivated portions show every shade of green, and in the distance is the little town with its white houses, brown-tiled roofs and its blue church tower. Shutting in the valley on the north rise the hills of solid white limestone rock, with sides almost vertical, to a height of over 300 M.; in their water-worn crevices and pockets, vegetation has taken root, and they are clad in verdure from base to summit. Away up near the tops grow slender palm trees, with white stems and the usual tuft of long, drooping leaves. Above these leaves, in August, there appears a flower, a delicate pink when first it blossoms, fading later to white and looking something like a bunch of ostrich feathers waving to and fro in the wind.

The work on this road was done under contract with a Cuban firm. This contract provided for the payment to the contractors the actual cost to them, plus 10½ per cent for all labor and for all materials incorporated in the work; \$1.25 per day per \$1,000 valuation of all plant employed during the time it was actually in use; \$1 per day for each animal employed; cost, plus the 10½ per cent, of forage for animals; and the net cost of all freight. The contractor was also reimbursed for his own necessary, approved traveling expenses to and from the work, and for the cost of transporting his laborers and other employees to the work. It was further agreed that when the work was completed the Government should pay the net cost of returning all his plant to Havana, whence it all had to be taken to the work.

A railroad runs from Havana to Pinar del Rio. All supplies and materials for the highway had to be hauled from the railroad station to the points where they were needed.

Work was begun on this road at the Pinar del Rio end in May, 1907, the beginning of the rainy season, which generally lasts from about May to about the last of October. Attempting to do road work during the rainy season was something of an innovation and necessarily made the work somewhat more costly. Work on this road was prosecuted through three rainy seasons. The fact that it was desired to put some of the local labor at work, without delay, was partly responsible for commencing at such a season of the year.

But little time was given for surveying and locating the route for this road; a somewhat elaborate survey of a possible route for about 4 kilometers from Pinar del Rio was found in the Department of Public Works; a bridge already built across the San Jose River some 7 kilometers from Pinar determined a point on the route; a line closely following the survey for the 4 kilometers was staked out, and then a line to the San Jose, selected after a hasty reconnaissance. The grading was started at once on this 7-kilometer stretch, and thereafter a number of possible routes for the remainder of the road were examined, and the best one finally chosen.

Stone was exceedingly scarce along the route of the road, only one quarry from which any considerable quantity could be obtained being discovered, and this a little more than halfway from Pinar to Viñales, at kilometer 15, where the road passed through a so-called "Mogote," an outcrop of blue limestone, which furnished an unlimited quantity of road metal. Some little stone was procured from two or three small quarries nearer Pinar del Rio, and a short stretch of road just outside this town was metalled with stone brought by rail from a quarry about 10 kilometers west of the town, and then hauled by wagon to the road. At the Viñales end of the road there were more "mogotes," and from one of them stone was procured for the last 6 kilometers.

ORGANIZATION

The officer in local charge was given as much latitude as possible; the total length of road was at one time divided into three districts, with an Engineer sergeant in charge of each; one enlisted man served as clerk; other enlisted men as timekeepers; one, or more when necessary, in charge of transportation, keeping track of the number of wagons and animals employed, the number of trips made, the length of haul, and the quantities of materials hauled. All surveying was done by Engineer soldiers, who gave lines, set grade stakes, and made calculations of quantities. Rations in kind were furnished the enlisted men, as a rule, and prepared by an enlisted man as cook.

The contractor kept his own timekeepers, etc., but they were all checked by engineer soldiers; work ordinarily commenced at 6 a. m. and continued until 6 p. m., with a two-hour rest from 11 a. m. to 1 p. m.

The contractor's orders for supplies were required to be submitted, for approval, to the officer in charge, and no bills for mate-

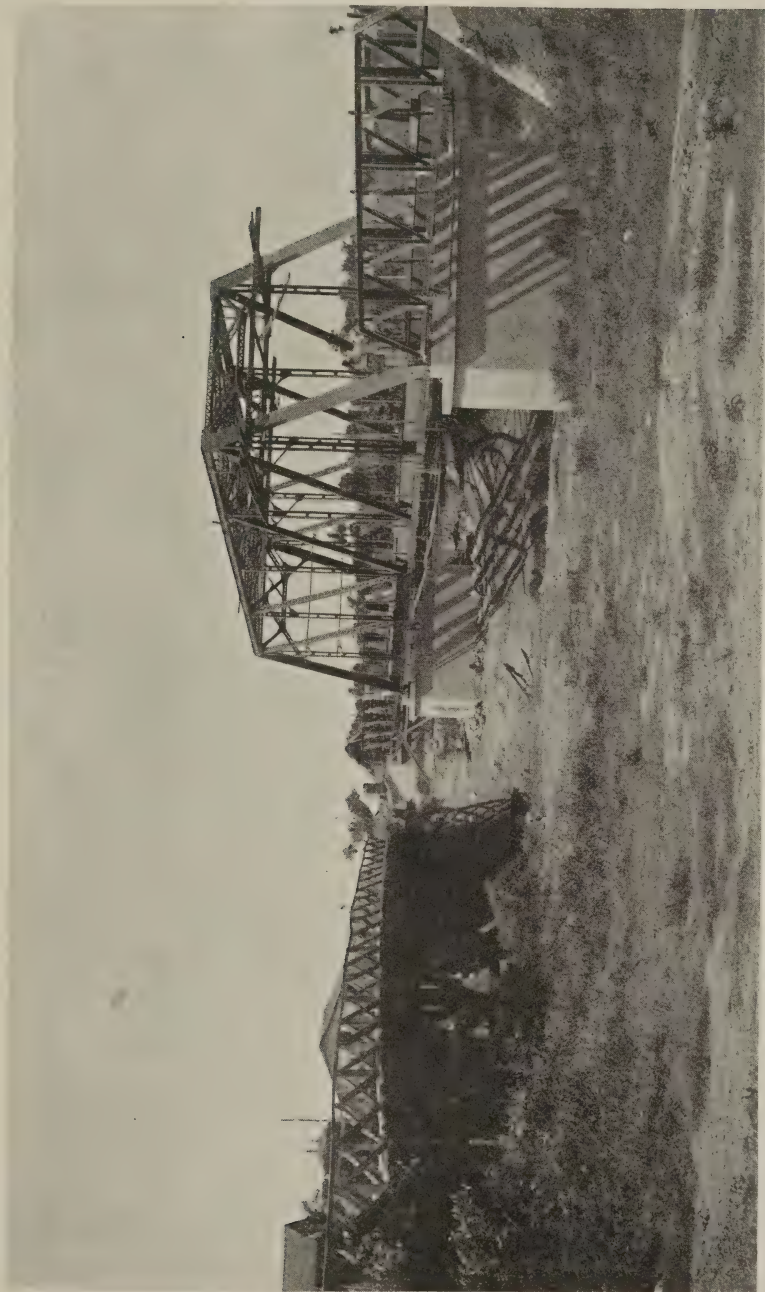


Fig. 1. Old and new bridges over Guama River at Pinar del Rio.

rials or services were paid unless approved by the officer in local charge. Every possible check was used and all available means were employed to insure the accuracy of the accounts rendered by the contractor, and to enforce due economy on his part. See remarks below on this form of contract.

COST KEEPING

An effort was made to keep accurately all unit costs, but in this particular the results were not as satisfactory as were desired. This was due to many reasons: the officer's time was so fully occupied that he could not do this himself; the enlisted men, while excellent in other capacities, were unfamiliar with such work, and but few of them could do it at all; work on different features was progressing simultaneously; men, materials, and plant were frequently moved from one job to another, making it a matter of no small difficulty to separate the costs. Some unit costs were secured, and are given below, as well as the approximate total cost of the entire road.

BRIDGES

For a span no greater than 10 meters the bridges were constructed with concrete abutments, the floors of reinforced concrete supported by I-beams, and designed to support a rolling load of 15 tons. Bridges over 10 meters were steel trusses on concrete abutments and piers. On this road there were six 10-meter bridges; two 50-foot truss bridges; one 110-foot truss bridge; one truss bridge with a channel span 120 feet, and two 50-foot shore spans.

TRACTION TRAIN

A traction engine and cars were purchased by the Department of Public Works and sent to this road for use, but failed to cheapen the cost of transportation, as had been hoped. This was due to several reasons: possibly, partly to inexpertness of the men who were employed to run it, but more decidedly due to the fact that the engine selected was not of the proper type, was poorly constructed, constantly breaking down, due apparently to poor material used in its construction, and to faults of manufacture. This engine was too wide for use on the road; special turning points had to be provided, and, as much of the road was on side hill cuts and on fills where turning space could not be provided, time was lost in going to and from a point where the engine could be turned. The maximum

haul from the quarry was about 8 kilometers, and though this was costly with wagons, yet, owing to the difficulties with the traction engine and train, wagon transportation was more economical, though the very best that could be gotten out of a four-mule team was about 30 kilometers actual travel per day; this made the average cost of hauling about 40 cents per cubic meter of stone per kilometer.

GRADING

Grading was done by hand and with drag and wheel scrapers. With the drag scrapers both mules and bulls were used; bulls were slow moving, but the steadiness of their pull and the ease with which they loaded the scrapers made them as efficient as the mules where the haul was short. Bulls required no forage, living on grass, while the forage for each mule cost, on an average, about 70 cents per day. Wheeled scrapers were not economical, as a rule, partly due to the inefficiency of the foremen and their inability to handle the outfit to the best advantage, resulting in crowding, delays in loading, and improper loading.

QUARRYING STONE

All drilling was done by hand; men who could operate steam drills could not be found. The cost of quarrying stone varied within wide limits, but, finally, it was arranged with a subcontractor to quarry stone at the largest quarry for 65 cents per cubic meter, this to include furnishing explosive, dynamite, and fuses, and breaking the stone into pieces of suitable size to enter the crusher.

CRUSHING STONE

Two small jaw crushers, capacity about 40 cubic meters each per day, and one gyratory crusher, capacity about 150 cubic meters per day, were used on the work. The cost of crushing the stone varied from 20 cents to 60 cents per cubic meter, the latter figure being much in excess of what it should have been.

ROLLING

A roller, operated by an internal combustion engine using alcohol, was used on this road. Owing to the relatively high cost of coal, it proved more economical than the ordinary steam roller; it weighed, however, but 10 tons, and was too light for rolling Telford, but gave good results rolling macadam.

To anchor the road metal, and to a certain extent to discourage driving off the edge of the metal, borders of large stones were embedded along the sides; the natives called these "paseos," or walks, though they were made rough and jagged intentionally to prevent passing over and along them. These "paseos" required about 1 1-3 M³ of stone per lineal M of road, added to the cost of the road, and as the interstices soon filled with fine material, they interfered with the drainage from the road surface, and were later omitted.

ROAD FROM VINALES TO SAN CAYETANO-ESPERANZA

The portion of this road from Viñales to San Cayetano, 16 kilometers in length, was constructed under a cost plus 10½ per cent contract, similar to the one described above, and by a Cuban firm. Esperanza is on the seacoast some 7 kilometers from San Cayetano, and the road between these two places was unfinished; the new road from Pinar del Rio, the nearest railway station, 26 kilometers from Viñales, was just begun, and it was absolutely impossible to get materials and supplies by rail. A single steamer from Havana, whence everything had to be brought, touched at Esperanza; this steamer had an absolute monopoly, and freight rates by it were abnormally high. The local owners of transportation, bulls and bull carts, had formed a "trust," and they gleefully charged all the traffic would bear. To haul a small stone-crushing plant from the port about 15 kilometers to the quarry took ten days and cost \$270. The existing road, or trail, was repaired, and some ten temporary bridges were built as soon as possible; thereafter all hauling was done by the contractors' mule teams in ordinary wagons.

From near Viñales, for about half its length, the road runs along the bases of towering "mogotes" and through gaps between them; along this part of the road, of course, stone was abundant, and the quarries were so selected as to reduce the average haul to a little less than 2 kilometers. The remaining 8 kilometers of the road had to be metalled almost entirely from a quarry at the southern end of this stretch, making the haul longer and more costly; a small quarry was opened about halfway along this piece of road, but the supply of stone that could be obtained from it at reasonable cost was soon exhausted.

There were six bridges of 10-M. span on this road, all built like the similar ones on the Pinar-Viñales road, and numerous culverts, but no truss bridges.

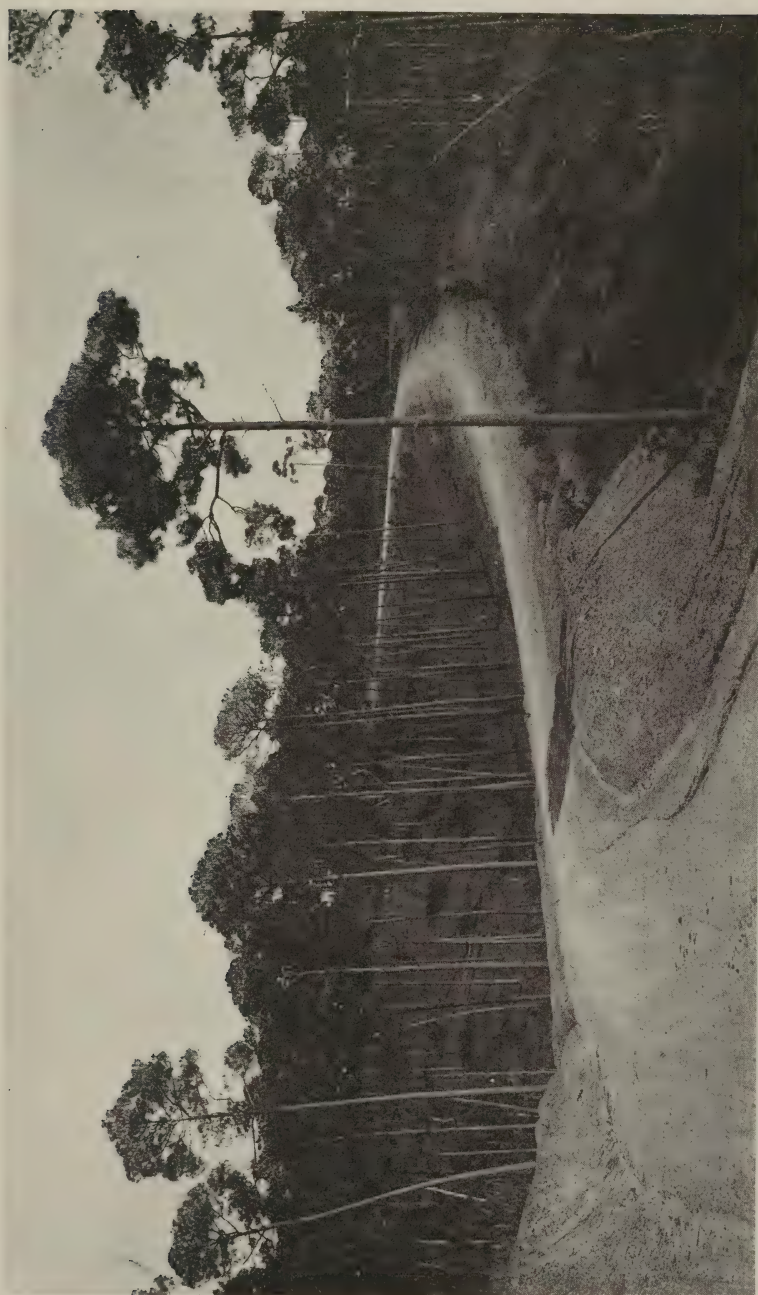


Fig. 2. Road in foothills near Kilometer 43; Vinales to Esperanza.

Beyond the northern end of this road, for about 2.5 kilometers, metal was placed on the roadbed which had been graded under another contract, making the total length of this road, finished, about 18.5 kilometers.

At Los Banos de San Vicente, some 6 kilometers from Viñales, there are warm springs strongly impregnated with sulphur; a short distance farther, but a little off the road, there is one producing copper mine.

ROAD FROM GUANE TO LUIS LAZO

Length, 33 kilometers. This road was constructed by a firm composed of Americans under a cost plus 10½-per-cent contract.

Leaving Guane, this road crosses a depression, over which it was carried on a fill about 1 kilometer long and 3½ M. high, with an opening 50 feet wide for drainage, spanned by a steel truss bridge.

The first available quarry was about 5 kilometers from Guane; thereafter, for about 25 kilometers, quarries were opened close to the road, and so located that the haul was short for both Telford and crushed stone. At the Luis Lazo end of the road the maximum haul from the quarry would be about 4 kilometers. This road was longer than any of the others, and was not entirely finished when the American intervention ended.

When it was commenced, the then terminus of the railroad was some 12 kilometers from Guane, the road over which all supplies had to be taken in was execrable, and it was nearly a year before the railway was extended to Guane.

BRIDGES

There were two 50-foot truss bridges, one such bridge with two 90-foot spans, one with a 70-foot span, two with an 80-foot span each, one with a span of 100 feet, one with a channel span 100 feet and two shore spans of 50 feet each.

PIECE SYSTEM

On this road the piece system of doing work (see below) was applied more extensively than on any of the others, and with excellent results. All work that it was possible to do in this manner was so executed—grading, quarrying, mixing and placing concrete in bridge piers, laying Telford, spreading crushed stone.

Leaving the Luis Lazo valley, the road runs west for several kilometers through a narrow gorge between high "mogotes" along the Cuyaguাতেhe River, the second largest stream in Cuba, which it



Fig. 3. Typical old road, worn to a depth of two meters; Guane to Luis Lazo.

crosses twice. The Cuyaguatêhe is an ever-flowing stream, one of the few rivers in Cuba which has, apparently, never been known to run dry; it enters the Luis Lazo valley through a natural tunnel, more than a kilometer long, under the "mogotes;" at ordinary stages of the river this tunnel can be traversed by men on foot, but the high-water marks are well up on the sides of the tunnel, and in times of flood the stream carries a great volume of water, overflows its banks, and frequently does considerable damage.

The contractors used a traction engine of their own, of a type which proved more satisfactory than those purchased by the Government. With it there were some flat-bottomed, side-dump cars, from which the broken stone did not unload easily; this was remedied by putting in false bottoms about one-half M. high along the axes of the cars, sloping to the outer edges, and increasing the height of the sides of the cars to compensate for the space thus taken up.

STEAM SHOVEL

A small steam shovel was used in making the fill about 1 kilometer long across the low ground just north of Guane; the average height of fill, 3 M.; side slopes, 1 on 1; top width, 7 M.; material hauled in dump cars from shovel to fill; cost, 42 cents per M³.

ROAD FROM SAN JUAN Y MARTINEZ TO PUNTA DE CARTAS

Length, 16.7 kilometers. It was decided to undertake this road by hired labor. For a little over 5 kilometers from the sea-coast the route of the road ran through a swamp, whose elevation was only a little above high-tide level, which was frequently flooded by storm tides, and invariably so during rainy seasons, and when the San Juan River, flowing through it, overflowed its low banks. It was necessary to carry the road on embankment for most of this distance; material of which to make this fill was hard to obtain in the swamps, and this added largely to the cost of the road.

The only quarry where stone could possibly be obtained was about 1 kilometer from the inland end of the road, so that the maximum haul for stone was about 18 kilometers, also very costly. At the beginning, the Government had but little plant available for this work, and it was necessary to purchase almost everything from picks and shovels to a complete stone-crushing plant; all the cost of this plant, about \$50,000, was charged to this one road, and figures in the total cost as given below. The deterioration of the

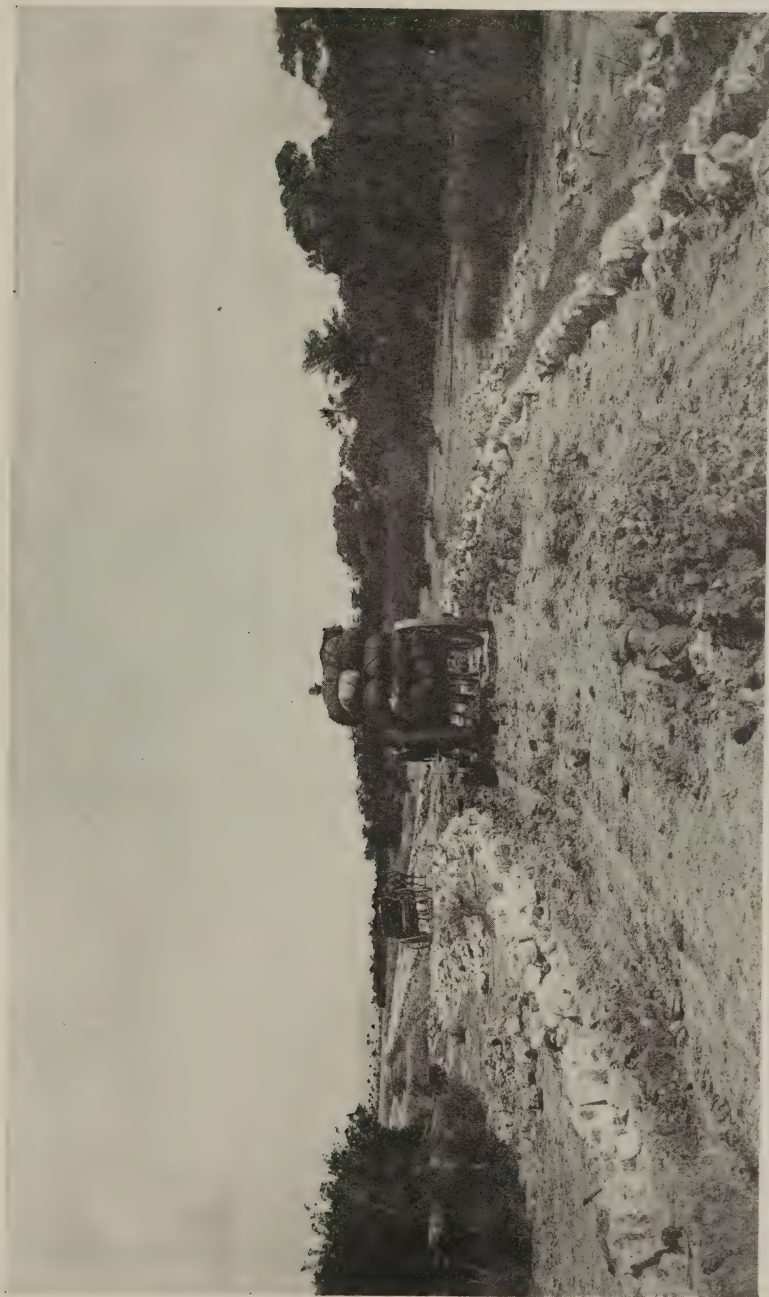


Fig. 4. Old road near Punta de Cartas.

larger pieces of this plant was not great during the progress of the work, and it was available for use elsewhere when this road was finished. As it was expected that other roads in the vicinity would be built, and as the quarry was the only one in the neighborhood, the stone-crushing plant was installed in a substantial building, where it would be protected and could be operated during rainy seasons. A traction engine and cars, similar to those used on the Pinar-Viñales road, were bought by the Public Works Department for use on this road, but the experience with them was practically



Fig. 5. Kilometer 12; new road from San Juan to Punta de Cartas.

the same as with the traction train on the Pinar road; the engine was so wide that nothing else could pass it on the road, it could not turn around on the road, and turning places were hard to find; there were constant breakdowns, due, apparently, to poor material and poor workmanship. Most of the hauling was done with mules in dump wagons and slat-bottom wagons holding about 1.5 M^3 of stone. By keeping one engineer soldier continually after the transportation, it was found possible to get about 48 kilometers a day travel by a mule team. By fixing a long and short haul the teams made a round trip on each haul per day. The wagons were loaded in the late afternoon and driven to the stable, about 2 kilometers

along the road from the quarry; they started the next day at about 3 a. m. on their long haul, returned to the quarry, made their short haul, back to the quarry, loaded for next day and went to stable; they rested for about three hours in the middle and hottest part of the day. Later, a considerable amount of hauling was done by bull teams, which made slower progress, but the price paid made the cost of hauling per M^3 no greater.

On this road the only work done by the piece system was the quarrying; the officers in local charge, and the soldiers assisting them, were not familiar with it, and at first did not speak Spanish well enough to manage it. All these men did acquire a good working knowledge of Spanish after a time. At first, one fine, old sergeant reasoned thus with a laborer demanding more pay: "Usted can hablar till you morir but no get mas pagar." The man seemed to understand.

There was one truss bridge erected on this road over the San Juan River; the abutments built by the Government, the bridge, 130 feet long, furnished and erected by contract. In building the abutments of this bridge, as many large stones as possible were embedded in the concrete, thereby reducing the cost per M^3 considerably. Care was taken to see that the stones were clean and thoroughly wetted before they were put in place. The cement cost \$4.15 per barrel at the site; sand was obtained from the river bed; broken stone was hauled from the quarry 1.5 kilometers distant; this concrete cost \$9.50 per M^3 .

COST OF STEEL BRIDGES

The steel truss bridges were in accord with the standard designs of the Department of Public Works, and were all purchased in the United States; the steel cost f. o. b. Havana \$75 per ton of 2,000 pounds; it was shipped by rail from Havana, and, in some cases, from the nearest point on the railway, had to be hauled on wagons 20 kilometers and more. The price paid for erection was \$30 per ton; this included furnishing and placing the false work, removing it after the bridge was erected, painting the superstructure two coats of paint, and putting in place the flooring, paint and lumber for flooring being furnished by the Government. The bridge flooring delivered at the site cost from \$48 to \$60 per 1,000 feet, B. M.

On all this bridge steel, though it was imported for the Government, the Treasury authorities exacted the payment of the duty.

As this was material for use on the roads, and as the amount paid for duty was part of its cost to the contractor, under the contract the amount paid for duty was duly repaid them, plus their 10½ per cent. This matter was explained at length orally and in writing to the officials, but they declined to change their ruling, and required the duty to be paid to the Treasury Department, and a few days later the Department of Public Works had to pay back to the contractor the sum paid for duty, plus 10.5 per cent.

PIECEWORK

It was found in Cuba that work on these roads was most economically performed when arrangements or agreements could be made to have it done by piecework. This was true of the grading, quarrying, hauling, stone crushing, laying Telford, spreading macadam, rolling, making, and placing concrete; work under all the above heads was done on one or more of the roads by this system. The native workmen organized themselves into gangs under a foreman, or "Capitaz," of their own choosing, and would take the jobs of grading, etc., by the M³, and practically invariably by this system the work was done more cheaply than by day labor.

The grading on all these roads varied from solid rock, through cemented gravel, stiff clay, sandy clay, to pure sand. When paying for grading by piecework, the price paid depended upon the nature of the material, and was rarely agreed upon in advance; as a rule, the engineer fixed this price fortnightly, after the work was done; a careful record was kept of the number of men working in each gang, of the amount of material moved, the hours worked, upon which no restriction was placed, and a note as to energy with which the work was prosecuted. When the work was satisfactory, as a rule the price per M³ agreed upon was such as to give the men a little more than they would have earned by day labor. It was interesting to note how keenly some of them watched and checked the engineer's measurements and calculations.

The stone quarried would be piled so that it could be measured; the quarry men would utilize stumps to swell the cubic contents of their piles, and would leave domed or arched-shaped vacancies therein, if they were not watched, sometimes spending more time on such devices than it would have taken to quarry and pile the stone

which would have filled such spaces; but, as a rule, they were fairly honest and, in their way, hard workers when the amount they earned depended thus upon their own exertions.

CONCRETE

American cement was used entirely in making concrete. There is a cement-making plant at Havana, but the price of its product was but a few cents less per barrel than for well-known brands of cement made in the United States, while the quality of the Cuban article was not so good. American cement delivered at points on the railroad about 200 kilometers from Havana cost, on an average, about \$3.75 per barrel; to this had to added the cost of hauling to the site of the work, often a long distance from the railroad. Another item which added largely to the cost of concrete was the unexpected difficulty in procuring sand at inland localities; very little sand was found in the beds of the streams, and that which was found was poor in quality, and frequently had to hauled several kilometers; crusher dust was used when it was available.

Concrete varied in cost from about \$9 per M³ in the abutment of the San Juan bridge, where sand was near at hand, and where many large stones were used in the mass, to about \$22 per M³ when placed in small quantities in culverts, etc., in places where the materials had to be hauled long distances.

The itemized cost of the 1:3:5 concrete in the abutments for the Guama bridge, on the outskirts of the town of Pinar del Rio, was as follows:

Cement	\$3.65
Sand	0.21
Small stone	0.85
Large stone	0.13
Re-enforcement	0.16
Materials for framing.....	1.53
Excavation	0.89
Labor for framing.....	0.97
Labor mixing and placing.....	2.19
Total cost per M ³	\$10.58

The labor cost of making macadam road 5-M. wide, exclusive of

grading and of cost of material, per M. of length, was about as follows:

	<i>Per linear meter</i>
Boxing and laying shoulders of large stone.....	\$0.225
Spreading macadam	0.075
Spreading binder	0.033
Sprinkling	0.030
Rolling	0.367
Total	<u>\$0.73</u>

KILOMETER POSTS

Kilometer posts marking distances along the highways had formerly been of cut stone, costing \$10 each at the quarry; for these there were substituted posts made of concrete, of simple design, costing \$4.88 in place.

It may be interesting to give some of the average prices of materials in Cuba, for comparison with prices in the United States:

Alcohol, per liter.....	\$0.40
Bran, ton of 2,000 pounds.....	40.00
Corn, ton of 2,000 pounds.....	36.20
Hay, ton of 2,000 pounds.....	40.00
Oats, ton of 2,000 pounds.....	69.25
Cement, per barrel.....	3.75
Coal, bituminous, per ton of 2,000 pounds.....	6.85
Lumber, per 1,000 feet, B. M.....	50.00
Oil, illuminating, per gallon.....	0.36
Oil, machine, per gallon.....	0.43
Dynamite, per ton of 2,000 pounds.....	412.65

The prices above are for materials delivered at the railroad stations nearest the work, and to them must be added the cost of hauling.

The total amount expended on all these four roads under American supervision was \$1,628,000. Of this amount the truss bridges, whose aggregate length was 1,370 feet, with their piers and abutments, cost, finished, approximately, \$100,000; the plant purchased for hired labor work cost about \$50,000, and it was worth to the Government \$40,000, after deducting a fair percentage for wear and tear; of the Guane road, but about 12 kilometers were entirely finished, but all the remainder, 21 kilometers, was graded, and all the stone for this stretch had been quarried. Adding to the lengths of roads given above the 1 kilometer made in the town of Viñales, 2.5 kilometers metalled beyond the end of the Viñales-San Cayetano

road, and 1 kilometer made into quarry at San Juan y Martinez, the aggregate length of road entirely finished was about 73 kilometers, and the actual net cost, deducting cost of bridges, and amount spent on incomplete road and value of plant, was about \$1,275,000, or something over \$17,000 per kilometer, a cost which is very high, compared with the cost of similar work in the United States, but which, for reasons given below, was as low as it could be kept, and not unreasonably great when all the existing conditions and difficulties are given due weight.

COST PLUS A PERCENTAGE CONTRACTS

This form of contract was entered into for three of the roads above described, two of the contracts being made with Cubans, one with an American firm doing business in Cuba. Under such a contract it is manifest that the greater the cost of the work, the greater is the contractor's gain. In other words, there is but little incentive for a contractor to do economical work, to institute and insist upon the many saving methods which can be and are employed when his profit depends entirely upon how cheaply he can do satisfactory work. Even if the contractor is honest and means to do economical work it is most difficult to get the best results from his subordinates, his foremen, and even from the ordinary laborers, all of whom are generally more devoted to the interests of the contractor than to those of the Government, and all of whom know that the contractor profits more if their work is done inefficiently and in the most costly manner. Securing economical work is immensely harder if the contractor himself is unscrupulous, and simply means to make all he can out of the job, and cares not at all what is the cost to his Government.

There are hundreds of ways by which such a contractor can increase the cost of the work, in spite of the most rigorous inspection and requirements. This is particularly the case when the inspecting force is not thoroughly familiar with language used by the workmen. With all conditions favorable, a trustworthy contractor meaning to give the very best results for the money expended, the work of superintending and inspecting under such a contract is easy, but under adverse conditions no form of contract is known

which will cause more annoyance, greater trouble, and give less satisfactory results.

REASONS FOR EXCESSIVE COST OF PUBLIC WORKS IN CUBA

The following is quoted from the report of the Provisional Governor for the year 1908: "The excessive cost of construction work in Cuba over that in the United States * * * may be attributed to several causes, the principal being: long, rainy seasons, involving added cost of work and expensive delays; all feed, lumber, machinery, fuel, cement, etc., must be imported at large cost; delays due to being away from base of supplies; man and beast are not as efficient in a tropical climate; inefficiency of labor, an ordinary man doing in Cuba half the work at nearly as high wages as the laborer in the United States; difficulty in obtaining trained mechanics and foremen at reasonable wages."

The conditions throughout the island, and especially in the western part where these four roads were built, placed the agriculturist who lived at any appreciable distance from the railroad or a seaport at a marked disadvantage. A portion of the benefit derived from the new roads may be gathered from the statements in the report of the Governor for 1908 that "The road from Pinar del Rio to Viñales and Esperanzo reduced the price of passenger transportation from \$15 to \$1.50, and the time of the trip from three days to three hours. The cost of transporting tobacco from the Viñales valley to Pinar del Rio, the nearest railway station, was reduced from \$3 per hundredweight to \$1 per hundredweight, and as the trip can be made in a few hours, instead of days, as heretofore, the danger of the tobacco being injured by exposure to sun and rain is reduced to the minimum."

Other roads cut transportation charges in half; in addition, by giving access, in many cases, to both the seacoast and railroads, there was a reduction in freight rates by common carriers. On many of the roads automobile 'bus lines were established and vigorously patronized.

DETERIORATION OF CUBAN ROADS

Macadam roads in Cuba, as elsewhere, deteriorate, and demand constant care to keep them in proper condition. Several reasons operate in Cuba to make their maintenance costly; the stone available for road construction is limestone, which pulverizes under traffic and forms a very fine dust; except in the towns, the roads are not sprinkled, and, during the long, dry season, much of the

top dressing is blown away; the rains in the wet season are heavy, the ditches frequently clogged, and the subgrade becomes saturated so that the traffic then forms ruts and inequalities, which, if not repaired, rapidly grow worse; in spite of regulations governing traffic, it is practically impossible to keep the narrow-tired, heavily loaded "carretas" off the roads; these vehicles not infrequently bring upon the roadway a pressure of from 1,500 to 2,000 pounds per inch width of tire, most destructive to the best built road; these vehicles are so wide that in passing each other they often run on the edge of the road metal, breaking it there, or even off the metal entirely, making ruts, which rapidly enlarge during the rains.

PRESERVATION OF ROADS

At intervals of about 6 or 8 kilometers along the roads the Government has built road houses, in which are lodged usually two laborers, and where are kept the necessary tools for repairing the roads. There are also overseers, who usually have charge of some 20 to 30 kilometers of road; the overseer and the laborers are supposed to keep the road in repair, but their work is frequently poorly done. Grass grows readily on the strip of earth bordering the road metal on each side; if encouraged, and simply kept trimmed, this grass would assist in preventing erosion, but it was almost impossible to keep the laborers from cleaning this strip of grass with hoes and destroying the roots. The road overseers are paid \$900 per year and furnished with quarters; the laborers, \$360 per year, with quarters. The average cost of the houses built for these employees was not far from \$4,500 each. At each of the laborers' houses there are kept one or more draft animals, with harness and carts and the necessary tools for the care and repair of the roads. A steam roller is also provided for use on the section under each overseer.

The interest charge on the first cost of the houses, animals, tools, etc., allowing a moderate percentage for deterioration, and adding the annual salaries of the employees, gives an aggregate cost for maintaining these roads of about \$200 per kilometer per annum. To this must be added the cost of materials, and the appropriation is further charged with a part of the salaries of the provisional engineering force and also of the Department of Public Works in Havana; how much these add to the cost is uncertain, but it is understood that the Department estimates the cost of the upkeep of these roads at not less than \$400 per kilometer per annum.

When the American intervention ended in April, 1909, some of the roads then unfinished were under contracts which the succeeding Cuban Government was pledged to carry out. After such contracts are completed, whether or not the Cubans will continue this good work is problematical. No expenditure of public funds will bring a greater return and be of more benefit to the island, and it is certainly to be hoped that a portion of the yearly revenue may be devoted to continuing the construction of good roads.

Field Engineering in 1908

During 1908 the Japanese issued a new Manual of Field Engineering, which follows the lines of the German *Feldbefestigungs Vorschrift, 1906*,* with profiles of similar shelter trenches. These are, for the most part, constructed with a deep, narrow trench, with nearly vertical sides to protect against field artillery. * * * Among other means of keeping trenches invisible from a distance, the Russians say that it is necessary to keep the surrounding grass and earth from being trodden down, or it is sure to betray their position to distant observers with good field glasses. * * *

In open country, closed redoubts are still looked upon as the chief form of field defense and they must be surrounded by formidable obstacles. Those of stronger profile must get the earth from an outside ditch, which is itself an obstacle. Traverses to lessen the effect of shell splinters are required. The Russians made these with passage room around the front, as well as in the rear. They made them, however, too high and conspicuous from afar. Headcover, with carefully made regular loopholes, proved too conspicuous. It was always found necessary to blind the loopholes. The Russians constructed blindages, or shelters, for the whole garrison of a redoubt.

The question of the occupation of villages and localities as defensive posts has again come to the front. Some think that they should be used only for reserves, the firing line being pushed well to the front in the open. The Japanese defended the well-built Manchurian houses with their high walls, about two feet four inches thick. These houses had nothing inflammable about them except the rafters and were often masked by surrounding trees. The Russians cut down most of the trees for banquettes, fire wood, etc., and suffered accordingly.

* Translation of the Von Löbells Reports on Military Matters in 1908.—*Journal of the Royal United Service Institution*.

THE ADVISABILITY OF A WATERWAY IMPROVEMENT

BY

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A synopsis of this paper by way of introduction will not only be of assistance to the reader in understanding its purpose, but will also aid him in understanding why it came to be written.

It is doubtless impracticable, in acts of Congress, or in orders to officers, covering examinations and surveys for proposed waterway improvements, to convey precise and detailed instructions in each particular case for covering the field of investigation. Apparently, in many cases, officers charged with such duties have been uncertain of the precise significance of these acts or orders, and by limiting their investigations to conform with a strictly literal interpretation have at times made reports which seem incomplete or inconclusive. Congress has, in special cases, indicated specific items to be covered by an examination or survey, yet, in most cases, the general terms used in the act permit of a more liberal interpretation. Is it not safe to assume that Congress intended, in specifying particular items, that those items should be included, rather than that all items not specifically mentioned should be excluded from the investigation? The broader interpretation of laws covering examinations and surveys may be expressed by the phrase—*the examination or survey of the specified waterway shall determine the advisability of its improvement, and, if advisable, the extent of the improvement.* The case of an artificial waterway or canal will be covered by the expression—*the advisability of providing a navigable channel at the specific locality and its capacity.*

In 1874 Congress investigated the subject of transportation between the interior and the seaboard, and practically covered the very wide subject of the advisability of providing navigable waterways from all points in the interior to the Atlantic and Gulf seaboard.

Individuals and organized bodies of citizens have recently taken

up with vigor the subject of waterway improvement; some unpleasant criticisms have emanated from various authorities with respect to the ability of officers of the Corps of Engineers to deal with questions of water transportation; it becomes, therefore, important for officers of the Corps to thoroughly study this subject, as well as its related subjects, and so prepare themselves that their examinations and reports will be complete, accurate, and conclusive. To successfully perform this task, it is necessary to know, not only the engineering features of waterway improvements, but also their use and utility, especially in their relationship to the general subject of transportation. The question now arises, Is it possible to devise a method or system to be followed in determining the value or importance of any proposed improvement, or to enumerate all the elements which bear upon the advisability of a waterway improvement, so that an opinion formed from them will be a necessary conclusion rather than a random guess? An attempt will be made to answer this question, not with expectation of entire success, but rather in the hope of drawing out the views of experienced officers for the benefit of others who may be called upon to make, perhaps for the first time, a preliminary examination or survey.

Let us examine first the acts of Congress appropriating funds for the construction and maintenance of works of river and harbor improvement, to learn whether there are any general terms to which they can be reduced. They contain a section reading somewhat as follows:

The Secretary of War is hereby directed to cause preliminary examinations and surveys to be made at the localities named in this section. * * * No examination, survey, project, or estimate for new works other than those designated in this or some prior act or joint resolution shall be made, nor shall supplemental or additional reports or estimates be made unless ordered by a concurrent resolution of Congress. * * * In all cases a preliminary examination of the river, harbor, or other proposed improvement shall first be made, and a report as to the advisability of its improvement shall be submitted. If upon such preliminary examination the proposed improvement is not deemed advisable no further action shall be taken thereon without the further direction of Congress, but if the report is favorable, or if a survey and estimate be deemed necessary to determine the advisability of improvement, the Secretary of War is authorized to cause surveys to be made and the cost and advisability to be reported to Congress.

The river and harbor act of March 3, 1909, adds to the above, that every report submitted to Congress in pursuance of this section, in addition to full information regarding the present and

prospective commercial importance of the project covered by the report, and the benefit to commerce likely to result from any proposed plan of improvement, shall contain also such data as it may be practicable to secure regarding terminal and transfer facilities, the development of water power, and such other subjects as may be properly connected with such project.

A careful reading of the various acts of Congress referring to river and harbor improvements does not disclose that Congress has given any further, or additional, general instructions covering methods of determining the advisability of improvement. These acts, however, contain sections in which special instructions are given covering the examination of special localities. For example, in the act of June 13, 1902, for the purpose of further surveys and report upon the project for improving the Connecticut River between Hartford, Conn., and Holyoke, Mass., a board to be designated by the Secretary of War was required to personally examine the improvement proposed by the officer in charge, and report thereon, with reference to the probable cost of said proposed improvement, the commercial advantages, if any, to be derived from such improvement, and such other information as the board may deem essential. In estimating the probable cost of the improvement the board was required to take into account both direct and consequential damages and the annual cost of maintaining the improvement.

In the act approved June 13, 1902, the Secretary of War is directed to appoint a board to make an examination and prepare plans and estimates for the protection of the port of Galveston and the property of the United States located on Galveston Island from excessive storms, by a breakwater or other means, and submit the same, with a report upon the feasibility, advisability and cost thereof, and the probable effect of such improvement upon the general condition of the port and its commerce.

In the act approved March 3, 1905, the Secretary of War is directed to appoint a board to examine the Ohio River and report the necessary data with reference to the canalization of the river, and said report shall include the probable cost of such improvement, the probable cost of maintenance, and the present and prospective commerce of said river, upstream as well as downstream, having regard to both local and through. They shall also report whether, in their opinion, such improvement should be made, and whether other plans of improvement could be devised under which the probable

demands of traffic, present and prospective, could be provided for without additional locks and dams, or with a less number than is described in surveys heretofore made, giving general details relating to all of said plans and the approximate cost of completion thereof.

The act of March 2, 1907, provided for the appointment by the Secretary of War of a board to examine the Mississippi River below St. Louis. The instructions contained in the act, governing the action of the board with reference to physical features, are elaborate, but those referring to advisability are almost identical with those given above for the survey of the Ohio River.

The Isthmian Canal Commission, appointed by the President of the United States, in pursuance of the provisions of the act of March 3, 1899, received its instructions through the Secretary of States, who authorized it to pursue any line of inquiry which might suggest itself as being of interest or benefit. The act authorized the President to make full and complete investigation of the Isthmus of Panama and the Nicaragua route with a view to determining the most practicable and feasible route for a canal, with the proximate and probable cost of constructing a canal at each of two or more of the routes, and the cost of placing the same under the control, management, and ownership of the United States. The citation of the Isthmian Canal Commission is made in this place, not alone because of the instructions it received upon the subject of advisability, but also with the intent of referring later to its elaborate and voluminous report on that subject.

It seems proper to mention here in immediate connection with the subject of boards appointed for the purpose of investigating advisability and feasibility of a waterway improvement, that the river and harbor act of March 3, 1909 (section 7), created a commission to be known as the National Waterways Commission, to be composed of Members of the Sixtieth Congress, who shall be Members of the Sixty-first Congress as well, as follows: Five Members of the Senate and seven Members of the House of Representatives, whose duty it is "to investigate questions pertaining to water transportation and the improvement of waterways, and to recommend to Congress such action as it may deem best upon these subjects."

The above citations embody essentially all instructions or directions given by Congressional acts governing the method of determining the advisability of a waterway improvement. It is seen that the expressions used vary greatly, and at best are very meager, but

it appears that Congress intended the investigations to cover the subject of *advisability of improvement*, sometimes with qualification, but at all times without limitation.

The preliminary examinations and surveys directed to be made by the Secretary of War in pursuance to general instructions contained in river and harbor acts are usually assigned to officers of the Corps of Engineers. Among the duties of the Corps enumerated in Army Regulations is the "execution of river and harbor improvements assigned to it." The phrase usually employed in acts of Congress appropriating funds for the construction and maintenance of public works on rivers and harbors is something like this: The following sums of money are hereby appropriated to be expended under the direction of the Secretary of War and the supervision of the Chief of Engineers. It therefore becomes the duty of *officers of the Corps* to make reports upon the *advisability of waterway improvement*. That this duty is one of great importance and that every officer should prepare himself by the study of all subjects connected with waterway improvements need not be enlarged upon.

For convenience of administration, the territory covered by the localities to be improved is divided into districts, of which there are now fifty-three, each in charge of an officer known as the District Engineer; and the districts are grouped into nine divisions, each in charge of an officer known as Division Engineer, whose duty it is to "overlook" the works in his district. In special cases, for example those mentioned above, the examinations and surveys were made by boards composed entirely of Engineer officers, or by mixed boards composed of Engineer officers, and civilians, or employees of the Government.

In all cases, however, reports of examinations, as well as surveys, must, by section 3 of the act of March 2, 1907, be examined and reviewed by a board provided for in section 3 of the river and harbor act of June 13, 1902, and the board can not extend the scope of the project contemplated in the provision of law authorizing the original examination or survey.

Section 3 of the river and harbor act of June 13, 1902, establishes the board and defines its duties in somewhat the following language: There shall be organized in the office of the Chief of Engineers, United States Army, a board of five Engineer officers, whose duties shall be fixed by the Chief of Engineers, and to whom shall be referred for consideration and recommendation all reports

upon examinations and surveys provided for by Congress, and all projects or changes in projects for works of river and harbor improvements, so far as the Chief of Engineers may deem necessary. The board shall submit to the Chief of Engineers recommendations as to the desirability of commencing or continuing any and all improvements; the board shall have in view the amount and character of commerce existing or reasonably prospective which will be benefited by the improvement, and the relation of the ultimate cost of such work, both as to cost of construction and maintenance, to the public commercial interests involved, and the public necessity for the work and propriety of its construction, continuance, or maintenance at the expense of the United States. The board shall, when it is deemed necessary, make personal examination of localities. The board is required to reduce to and to submit in writing for the records of the office of the Chief of Engineers all facts, information, and arguments which are presented to it in connection with any matter referred to it. Under certain conditions the board is also required to examine and report upon any project heretofore adopted by the Government or for which appropriations have been made as to the desirability of its continuance or of its modification.

Notwithstanding the length of the instructions to the Board of Engineers for Rivers and Harbors, it is to be especially noted that it is required to determine the advisability of improvement and to report all facts connected therewith, with no limit set to the scope of its investigation.

The duty of making the preliminary examinations and surveys provided for by river and harbor acts is usually assigned by the Chief of Engineers to the Engineer officer in whose district the proposed improvement is located, unless the act provides for the appointment of a board. The district officer is instructed to take up these examinations at once and to submit separate reports thereon (through his Division Engineer), including a statement whether or not, in his opinion, the river is worthy of improvement by the General Government, together with the facts and reasons upon which his opinion is based. Information in regard to the present and prospective demands of commerce and the character and amount of such commerce, whether general or local, and its value, is particularly desired. He is, therefore, to make a full and careful presentation of all obtainable facts and data in regard to the commerce which would be affected by the contemplated improvement. Per-

sons who have shown an interest in the improvement, and others whose local knowledge renders their opinions of value, are to be consulted and should have a full opportunity to express their views. The examination report is expected to present only such facts as may be necessary to form an opinion as to the worthiness of improvement by the General Government and should contain no plan except in a general way, *nor any estimate of cost* of the work proposed. If a locality is reported by the district officer to be worthy of improvement, or if in his opinion a survey and estimate should be made to determine the advisability of improvement, an estimate is to be submitted of the least amount required to make such survey as may be necessary for the preparation of a report with plan and estimate of the cost of improvement. If a locality is not deemed worthy of improvement, the district officer is required, in order that the merits of each case may receive full and complete consideration, to inform any parties known to be interested, that they may submit for the information of the Board of Engineers for Rivers and Harbors, to which all examination and survey reports are referred, any statements, facts, or arguments that they may desire in regard to the necessities for such improvement.

If the Secretary of War should authorize a survey to be made, the district officer is then required to submit a report based upon the results of the survey, containing a further expression of opinion as to the extent of improvement justified by the commercial and other interests involved, both present and prospective, together with any additional facts and arguments that may be deemed essential to permit of a full and complete consideration of the merits of the case, both by the War Department and by Congress.

The above extracts show that in preliminary examinations the district officer is not instructed to follow any special method in making his investigations and reports so far as concerns *advisability*. He is not told how to proceed, and, in fact, he is left quite free to use his own judgment in the entire matter, except with respect to the cost of the proposed work, the collection of certain commercial statistics, and the demands of commerce. Congress can not be expected to indicate detailed methods to be followed in each of the great number of examinations, some comparatively unimportant and some of great magnitude. Having a body of engineers trained along such lines, an indication of the result desired should be sufficient, leaving the manner and method to be worked out by its skilled experts.

The fact being established that the investigation as to *advisability* is left almost entirely to the discretion of the officer, the question arises, How shall this be conducted and what shall be its scope? Is there any method or plan which may be successfully followed for determining the worthiness or advisability of improving a waterway? The interest which officers of the Engineer Corps have in such method or plan, and, in fact, its great importance to them, is beyond controversy. Is it possible to devise a method which can be followed in more than one case, in many cases, or in all cases? Methods simplify work enormously. Certainly Congress has laid down no method, and text-books on waterway improvement confine themselves to engineering features. Where, then, are we to look for a satisfactory solution?

Again, a method would lead the various authorities, now required by law to express their opinions and make recommendations, to reach, in every case, the same conclusions. Can we discover and tabulate all the elements which affect a proposed improvement and by weighing them arrive at a clear and just conclusion, or must there always be some secret, mysterious, or hidden influences which the district officer must guess at and balance with the known elements in order to form his opinion?

The time is certainly ripe for a study of this subject by officers of the Corps of Engineers, and for the dissemination of information to terminate the unpleasant discussions now in progress over certain proposed waterway improvements.

A President of the United States has said in a message to Congress that "the Military Engineers have undoubtedly done efficient work in actual construction, but they are necessarily unsuited by their training and traditions to take the broad view, and to gather and transmit to the Congress the commercial and industrial information and forecasts upon which waterway improvement must always so largely rest;" and, again, "it is no longer wise or safe to leave the great work in the hands of men who fail to grasp the essential relations between navigation and general development and to assimilate and use the central facts about our streams." Whether this criticism be just or unjust can not become a question for discussion in this paper, but it is important that, so long as Engineer officers are required by law to express opinions upon the advisability of waterway improvement, "forecasts upon which waterway improvements must so largely rest," they so qualify themselves that their opinions can not be successfully attacked or

justly reversed. Congress has reposed confidence in the Engineer Department, and now that the subject of waterway improvement has been taken up so enthusiastically by organized bodies of citizens in all parts of the United States, the Corps of Engineers should prepare itself for a probable enlargement of its present duties in this connection.

No study of the general subject has apparently been made up to the present, and the purpose of this paper is to turn the attention of interested persons in that direction.

Before taking up any subject for original study, it is well to learn what has been done by others in the same line. We may search past reports upon examinations and surveys in the effort to learn whether any method or plan of investigation was followed, or we may perhaps even devise a plan by observing how others have treated the subject of advisability. It would involve a large expenditure of time and patience to examine every report on waterway improvement in various parts of the world, yet no study can be complete without so doing. A few reports, made in response to sections of certain river and harbor acts mentioned in preceding paragraphs, will be selected as illustrations in this paper.

A number of preliminary examination reports made in compliance with the requirements of the river and harbor act of August 5, 1886, are printed in House Executive Document No. 58, Fiftieth Congress, first session, from among the localities enumerated in the bill which were found to be in the opinion of the local engineer not worthy of improvement by the General Government, with the facts and reasons upon which such opinion is based. A study of these shows that they vary widely. Space does not permit an enumeration of these, and more valuable conclusions can be drawn from the four examples which follow, namely, the Connecticut River, the Ohio River, the Mississippi River, and the Panama Canal.

CONNECTICUT RIVER

A survey of the Connecticut River between Holyoke, Mass., and the foot of the Enfield Rapids was directed to be made by the Secretary of War under the provisions of the river and harbor act of June 3, 1896, by the local officer in charge at New London, Conn., whose report may be found in House Doc. No. 136, Fifty-fifth Congress, second session.

The report describes the physical features of the river, discusses its commercial importance and military value, the effect of the pro-

posed plan of improvement upon the existing water powers, and closes with the statement, "in view of the estimate of cost and the commercial importance of the stream * * * I am of the opinion that the Connecticut River between Hartford and Holyoke is worthy of improvement * * *." The estimated cost, including land, buildings, flowage, and contingencies was \$2,075,000. The report states that the commercial importance of the Connecticut River in this part of its course must be arrived at by deduction from the statistics of commercial activity in the tributary district. Navigation is not now, and has not been for some years, on a competitive basis, and hence no commerce has sought this route. Only the cities and towns of some importance in the tributary district can be considered, because it is only for such that statistics are available. The section of country which would be benefited by a water terminus at Springfield with the rail feeders and distributors which such a terminus will naturally command is estimated to contain 350,000 inhabitants and property to the value of \$249,000,000. The four cities of Holyoke, Chicopee, Springfield, and West Springfield have a population of 116,000 and property valued at \$106,000,000. The manufactories of the four cities consumed materials valued at \$24,500,000 and made \$47,500,000 worth of product, which may be conservatively estimated at 500,000 tons per annum. The annual consumption of coal of the four cities is stated to be 447,000 tons. The aggregate freight tonnage, exclusive of railway supplies, is reported by the railroad freight agents at 1,800,000. The proportion of the total tonnage, say, 2,000,000, which would avail itself of water carriage is a matter of conjecture. It is within limits to say that 25 per cent will actually go by water. But a more important fact is not conjectured, and that is that the freight rates on the entire traffic will be substantially the same as though all of it went by water. It is from this point of view that the real importance of the river must be judged. The total actual reduction of freights, directly and indirectly accomplished, will nearly equal the cost of creating a suitable navigation, and the saving on the traffic that will actually use the improvement would pay a return on several times its cost. The report, however, gives no figures to prove this last statement.

A special board appointed under provisions of the act of June 13, 1902, already alluded to in a preceding paragraph, was directed to report upon the probable cost of the proposed plan of improvement and the commercial advantages to be derived from it. After stating

that "therefore any commercial advantages arising must be based upon prospective commerce," the board gives a table containing a list of towns and settlements lying upon the stretch of river under consideration, all of which are dependent upon railroads without competition. Twelve towns are named, having a population of 159,458, value stock used \$31,918,617, value manufactured products \$62,678,437, capital invested in manufacturing \$59,304,384, and a table of tonnage of coal of 565,000 delivered at certain of these towns, which material would be subject to direct competition between river and railroad transportation. The Board also says:

Should the improvement be made, competition would exist between the railroads and water transportation, and large amounts of bulky material would undoubtedly be carried up the river at cheaper rates than they can be carried by the railroad.

The report of the special board was reviewed by the Board of Engineers for Rivers and Harbors. The latter Board held public hearings, at which it was developed that—

The principal object desired by those in favor of the improvement is primarily to create competition between rail and water with a view to securing lower freight rates, and, secondarily, to obtain quicker deliveries of freight to New York City than non-competitive transportation now affords. * * * At an assumed cost of \$3,000,000 the annual interest charge at 3 per cent would be \$90,000. Adding to this the sum of \$50,000 for maintenance, and assuming the annual tonnage that would avail itself of the new waterway at 500,000, it is seen that the cost to the Government would be 28 cents per ton. * * * Owing to the large cost as compared with the probable benefits, and the insufficient depth of water in the channel below Hartford, the board is of the opinion that the proposed improvement * * * is not worthy of being undertaken by the General Government.

The Chief of Engineers transmits these reports to the Secretary of War and comments upon the fact that the Board of Engineers bases its adverse conclusion upon the amount of traffic which may be carried by the river, omitting consideration of the traffic of probably 1,500,000 tons indirectly affected by competition. He also says:

I do not know that the hope of lowering non-competitive freight rates by improving a waterway and thereby introducing a competing element for a special locality has been generally accepted as good ground for undertaking an improvement on the part of the General Government, but it is certainly frequently urged as such a ground and in this case appears to be the principal one. It appears very questionable whether the expectation of benefiting the

towns above Hartford in this manner warrants the General Government in undertaking the improvement, and thus spending a large sum for the purposes named, especially as it may be possible to accomplish the ends sought at less expense by more direct methods.

The river and harbor act of March 3, 1905, directed the reconvening of the special board "for the purpose of preparing and submitting an additional report on the improvement of said river by open channel work or methods other than those already reported upon."

The Board adds to its previous report the following statements:

It is believed by the Board * * * that the difference in the freight rate on coal as between Hartford, Conn., and Springfield, Mass., is 75 cents a ton, and this is exactly the rate of toll which the Connecticut River Co. is permitted to charge under its charter for freight passing through its canal. It would, therefore, appear that an improvement made by the foregoing plan would be of no benefit as compared with the present means of transportation.

The Hon. John R. Buck * * * speaks of their property as worth \$2,000,000. To purchase this and then make the improvement renders the work too expensive to be undertaken. The objection to this location (i. e., an entirely new location for the improvement) will require the purchase of right of way, the relocation of the railroads, both steam and trolley, and possibly the partial destruction of the village of Warehouse Point.

The Board expresses its opinion as before that the locality is not worthy of improvement.

The Board of Engineers for Rivers and Harbors adds no new facts to the report of the special board, but expresses the opinion:

That the third method (of improvement) suggested by the Special Board is well adapted to the conditions existing on this river, and that its cost, \$1,465,600, is justified by the present and prospective commerce of the Connecticut River. If, however, there is to be added to this cost any compensation whatever because of alleged injury to the works or the rights of the Connecticut River Improvement Company, or other parties claiming infringement of vested rights through this improvement, such additional cost would, in the opinion of the Board, make the total cost of the improvement incommensurate with its probable benefit to commerce. It is recommended that the improvement * * * be authorized * * * provided that all rights claimed * * * shall be ceded to the United States without cost.

The Chief of Engineers transmits these reports with the comment that "there may be justification for the proposed improvement * * * when the extensive private corporate rights that will be affected by any permanent works have been ceded to the United

States without cost.” (House Doc. No. 323, Fifty-ninth Congress, second session.)

The river and harbor act of March 2, 1907, appropriated \$5,000 “for investigation and further examination as recommended by the Board of Engineers” in its last report.

The district engineer officer to whom this examination was assigned reports that he understands that this estimate was based on a report submitted by him in compliance with a resolution of the River and Harbor Committee directing that it be ascertained * * * whether agreements could be made under which certain rights * * * which might be infringed by said improvement could be ceded to the United States without cost. He reports, first, his inability to obtain definite answers to his requests of the Connecticut River Company for information, and then continues in somewhat the following language: In the course of the study of this matter two points have been brought to his attention to which it seems proper to refer. These are, first, the need of the improvement, and, second, its cost.

All previous reports have, he believes, been based on the idea that the improvement of this section of the river has been asked mainly, if not entirely, as a means of regulating the freight rates over the railroads to the cities of Springfield, Holyoke, and vicinity, and not with any real expectation that any great amount of commerce would be carried on the river, although in all of the reports there have appeared statistics, given by interested parties, showing the probable amount of commerce which would be developed if the improvement was made. While it is probably a fact that the main object of the improvement in past years has been a means of regulating the freight rates, nevertheless the conditions that arose during the year 1907 showed the great value that those improvements would have in the commerce carried. During that year this section was not exempt from the congestion of the railroad traffic that was so general throughout the United States, and during the summer of 1907 it was not a question of rates, but it was a question of getting freight at any price to Springfield and Holyoke. The supply of coal became so low that it appeared more than once that the gas company might be obliged to cease operations on account of lack of fuel. Had navigation existed on the river, this condition would not have arisen.

The Division Engineer who acted upon the district officer's report expresses the opinion that “the cost is out of proportion to the

probable benefits, and the improvement * * * is not worthy of being undertaken by the General Government."

The Board of Engineers for Rivers and Harbors states that since it now appears that the Connecticut River Company declines to cede any of its rights to the United States, the plan recommended by the board is impracticable of fulfillment, and—

Should Congress decide to undertake this improvement at a cost of approximately two and a half million dollars, it is possible that some other plan involving about the same expenditure might be preferable. (House Doc. No. 1311, Sixtieth Congress, second session.)

The story of the Connecticut River seems a long one as told above. It covers eighty-eight pages of printed matter and a period from 1896 to 1909 and ends with the statement, "It is possible some other plan might be preferable."

OHIO RIVER

The examination of the Ohio River presents a simpler situation than that of the Connecticut River. The river and harbor act of March 3, 1905, directed the Secretary of War to appoint a board of engineers to examine the Ohio River and report, at the earliest date by which a thorough examination can be made, various things which may be concisely expressed in the following manner: The necessary data with reference to the canalization of the river, the approximate location and number of locks and dams in such river, with a view both to a depth of 6 and 9 feet; the probable cost of such improvement with each of the depths named, the probable cost of maintenance, the present and prospective commerce of said river, upstream as well as downstream, having regard to both local and through traffic, whether in their opinion such improvement should be made, whether other plans of improvement could be devised under which the probable demands of traffic, present and prospective, could be provided for without additional locks and dams, or with a less number than is described in surveys heretofore made, giving general details relating to all of said plans and the approximate cost of completion thereof, and whether an increased depth can be maintained by use of dredges in the said river from the mouth of the Green River to Cairo.

The board reports that a prediction as to that portion of the prospective commerce dependent upon the development of new industries caused by cheap transportation would involve investigations thought not to be contemplated in the instructions to the board, and

therefore confines its report on prospective local commerce to the general principles underlying the development of such commerce and to mentioning a few of the commodities and manufactured articles already developed that would likely seek a local market; it believes that—

In order to estimate the benefit which will accrue to the valleys of the Mississippi and Ohio rivers, it is not only necessary to discuss the kinds and quantities of freight carried on the present unimproved streams and the great increase in such kinds of freight which will occur upon a safer and more dependable waterway, but it is also necessary to investigate the mineral, agricultural and commercial resources of the system with a view to estimating the effect which cheap local and through transportation will have upon the development of new industries.

Under the designation prospective commerce the report gives statements regarding manufacturing establishments on the river, the population of the valley, the consumption of rice, sugar, coffee, and molasses, the imports into the valley from foreign countries, the use of iron ore, timber, agriculture, and cement production, and presents a map which shows the boundary of a territory which from a combined river and rail freight transportation standpoint is tributary to the Ohio and Mississippi River systems. The board endeavored to collect statistics at certain cities upon the following points: total freight movement, chief industries, sources of supply of raw materials, quantity of imported raw materials, effect of uninterrupted navigation upon the manufacturing industries, present receipts and shipments by river. The board discusses the subject of river transportation in general, time that goods are in transit by river and rail, and types of boats best suited to Ohio River traffic. There seems to be no proof that the proportionate decrease in the use of streams for general transportation is due to any other cause than the unreliability of such streams for such purpose in their unimproved condition. This assumes, of course, that railroads will prorate with river lines of transportation where the latter are reliable, and thus not burden freight seeking water transportation with a high local rate to and from the river and that the large shippers have no interest in one system of transportation over another and will route goods as the buyer desires, and that elevators and other auxiliaries to transportation are independent and equally available for all systems at the same price. Unreliability of river transportation has prevented the proper development of wharves, loading and unloading devices, and the larger shippers of finished products have

prepared for shipping only by rail, adding to the disadvantages that the intermittent river transportation is forced to bear. There seems to be a misconception as to the time required to deliver goods by river in comparison with that required to deliver them by rail. It can safely be stated that under present conditions, when a navigable stage may be relied upon, shipments of less than carload lots are generally delivered in less time than similar shipments are delivered by rail, and that on a reliable stream nearly all classes of freight offering in any quantities are delivered at least as quickly by river as by rail. The reported average movement of a loaded freight car per day in the United States is about 23 miles.

The board makes a comparison between the costs and benefits of 6 and 9-foot navigation and shows that the cost of transportation on coal, the largest item of shipments, is as 3 to 2, and that the minimum annual saving in freight costs on the entire commerce 13,000,000 tons, by using 9 instead of 6 feet will be \$2,280,000. The board having decided upon the engineering features of the locks and dams suitable for traffic on the Ohio, presents a table showing the number of dams required to complete the present 6-foot project, and for a 9-foot project, with estimates of cost for canalization of the entire river (\$63,731,488). After discussing the subject of dredging in the lower river and expressing an opinion upon its practicability, the board finally states:

It is believed that the probable demands of traffic present or prospective can not be provided for by any other plan of improvement not having locks and dams or having a less number of dams than those proposed by the board. In view of the enormous interests to be benefited by continuous navigation on the Ohio River and the great development which may be expected from such increased facilities, the board is of the opinion that the Ohio River should be improved by means of locks and movable dams to provide a depth of 9 feet from Pittsburg to Cairo.

The Board of Engineers for Rivers and Harbors held a public hearing at Pittsburg and made a personal inspection of the river from Pittsburg to Cairo. It reviews the report of the special board and adds to it much other information:

Nor does the board consider that the saving which would accrue to existing commerce by the proposed improvement would be sufficient to justify its cost. In fact, the losses claimed to be sustained by the coal interests due to delays in shipment under existing conditions are less than one-half the cost of maintaining the proposed waterway, and it is believed that as much coal is now shipped by water as there is a demand for on the lower rivers. A material increase in the commerce of the river must therefore be created by the improve-

ment and a change in the character of the freight carried to warrant such an expenditure. Nor is the board prepared to indorse fully the views expressed as to the benefits to be derived from river transportation over that by rail. Railroads possess certain inherent advantages which compensate in great measure for the cheapness with which freight can be moved by water. The railroad companies have become the great agencies for transportation in this country. They have connected the principal towns with cheap lines of communication penetrating the field, the mine, the factory, and the warehouse. They have expended large sums in developing their terminal facilities in the various cities through which they pass and have erected elevators and other auxiliaries to reduce terminal charges. By consolidating into vast trunk lines, the cars collected by the branches are moved long distances in train-load lots with great economy.

Lines of river transportation are restricted in location. They must follow the thalwegs of the larger valleys and can only penetrate a small part of the country. Except in the case of the comparatively few mines and factories which are situated on their banks it is necessary to transport by car or wagon from the shipping point to the waterways and then tranship and reverse these operations to reach the terminal, while the railroad can ship from the mine to the factory or warehouse without breaking bulk.

Branch lines by rail or wagon are a necessity to an efficient water route. But in determining the cost of transportation by water the cost of these lateral feeders is not usually considered, while it forms a large percentage of the cost of rail transportation.

On the main lines of the various railway systems freight is being transported in train lots at a rate of less than 2 mills per ton-mile and it is natural for the railroads to endeavor to reap the benefits of a long haul and not surrender the most profitable portion of their trade to a rival water route. It would be unreasonable to expect them to act as feeders to a water route at a rate per ton-mile the same as they now charge for carrying freight from New Orleans to Pittsburg in competition with it, nor can they be compelled to turn over to rival carriers their warehouses, elevators, and other terminal facilities which they have erected at great expense.

Distances by rail are considerably shorter than by river, which compensates to a certain extent for their greater rate per ton-mile. A short water route can not successfully compete with a great railway system for through commerce. To be a success it must be of such a length that the great transportation companies will themselves find it advantageous to ship over it.

The waterways connecting the Great Lakes have enormously developed in the past ten years, but the railways have reaped the benefits. Neither the Canadian canals down the St. Lawrence River, nor the Erie Canal across New York State have responded to the growth of the lake commerce. The success of the Great Lakes as a means of transportation has not resulted from competition between the great systems of transportation and outside parties, but from the utilization of the waterways by the railroads themselves, which have expended millions of dollars to improve their terminal facilities and have established the large fleets which navigate the lakes.

But the great cause of the failure of waterways as a means of transportation in the United States is that they heretofore have not generally followed a

commercial route, but have led from nowhere to no place. The river systems of the country flow generally in a southerly direction, while the trend of commerce has been east and west. Until within the last ten years a railroad running north and south was generally a financial failure. River systems have followed the same laws, their commerce has been confined to the products on their immediate banks, and that of not sufficient amount to justify their permanent improvement. That great waterway, the Mississippi River, has been improved by the General Government and is now being maintained from New Orleans to Cairo at the depth proposed for the Ohio and for several years has been maintained from Cairo to St. Louis at a depth of 8 feet, yet its commerce is insignificant except what it receives from the unimproved Ohio. The river commerce of St. Louis has declined from 812,185 tons in 1895 to 370,425 tons in 1905, notwithstanding the enormous commercial growth of the city in other directions. The recent railway development from the grain center at Kansas City to the Gulf has diverted a considerable barge commerce from the river to railroad lines by a reduction in rates that the river improvement could not meet.

The board makes some brief statements with respect to river and rail shipments in the Pittsburg District. Even in its unimproved condition the river has a marked effect on rail freight rates, the cheap rates quoted in the report as prevailing between New Orleans and Louisville, Cincinnati and Pittsburg, being directly traceable to its influence. Its effect on rail freight rates will be greatly increased if the proposed improvements are carried out. For these reasons the board is of the opinion that the improvement as recommended by the special board is worthy of being undertaken by the United States.

The Chief of Engineers in transmitting these reports to the Secretary of War comments in part as follows:

It will be noted, in the first place, that, by a plain inference, the conclusions of the report depend upon a conjectural future commerce rather than upon the commerce now existing or plainly in sight. It is in fact an assumption of the restoration of the field of commercial usefulness which the river enjoyed before the advent of any rival method of transportation. It is assumed that commerce will always seek the route which it finds cheapest, cost and convenience considered, that by the method of improvement proposed the cost and convenience of commerce in both directions on the Ohio River can be made less than by any other method of transportation, and that under such conditions the traffic will surely seek the river. Attention is called by the board of review to the fact that Congress has not up to this time sanctioned a project of such extent as this upon considerations of this character. Whether it ought to sanction either of these projects would appear to be a matter purely for legislative determination, based upon such data as are supplied by this report or as may be obtained by further inquiry. The original board and the board of review are both convinced that the probability of increased traffic is sufficiently strong to justify the proposed expenditure—this from the standpoint of ordinary business considerations—and from this standpoint I concur in this view * * *.

I entertain no doubt whatever that the development of a large future commerce, seeking the river in preference to other methods on account of the increased convenience and diminished cost of freight movement, depends absolutely upon a method of improvement which will have a tendency to remove or minimize the present vastly different conditions between upstream and downstream traffic.

MISSISSIPPI RIVER

The report of the special board appointed in accordance with the river and harbor act approved March 2, 1907, to make an examination of the Mississippi River below St. Louis to determine the practicability and desirability of constructing and maintaining a navigable channel 14 feet deep and of suitable width, is given in House Doc. No. 50, Sixty-first Congress, first session.

The board estimates the cost of constructing and maintaining a 14-foot channel by the most economical method at \$128,600,000 and \$6,500,000, respectively. As to present and prospective commerce, the entire commerce of the Mississippi River System, including all tributaries except the Ohio, was, in 1889, 12,492,535 tons and in 1906, 4,304,288. In 1908 a slight decrease as compared to 1906 is shown. Although the board sought to obtain information as to the prospective commerce which requires a 14-foot navigation, it received very little definite information in that direction. No actual large future development of commerce is yet in sight. The demand for increased depth appears to be more conjectural than real, and to be based mainly upon the idea that a deep water channel will of itself cause development of commerce, on the ground that business follows facilities. The Chicago public claims that the existence of a 14-foot depth out from the Great Lakes to the ocean through Canada demands a similar outlet through the United States, and that this should be by way of the Mississippi valley. The Upper Mississippi public claims that a deep waterway from the mouth of the Illinois River to the Gulf will encourage the shipment down the River of ores and flour from Minnesota and Iowa, and coal from Illinois, along with miscellaneous manufactured goods. The Lower Mississippi public claims that a deep waterway will encourage upstream navigation. The St. Louis Lakes-to-the-Gulf Deep Waterway Association and the St. Louis Merchants' Exchange claim that a large amount of the commerce now carried by rail parallel to the Lakes-to-the-Gulf route would be transferred to a deepened river, and that this transfer would leave the railroads free to take up an equal quantity of freight which they are now unable to handle be-

cause of restricted transportation facilities, and that a deep waterway between St. Louis and Cairo would bring more coking coal from the Ohio to St. Louis. The early completion of the Panama Canal also appears to be a prominent argument for deeper draft, since it will cause a development of the export trade to South America and the Pacific.

As to the desirability of a 14-foot waterway, the board, after showing by statistics that the great majority of vessels on the Great Lakes have a greater draft than 14 feet, in fact, on the ocean as well, concludes with the opinion—

That a 14-foot waterway is suitable for neither existing lake nor ocean vessels, that freight originating on Lake or Gulf will require transshipment to vessels adapted to its navigation, and that its principal value will be to provide for commerce that originates along its banks, or those of its tributaries, until the introduction of some form of vessel adapted to all conditions of navigation. When such a vessel shall be designed, there will be an immediate demand for a channel of greater depth than 14 feet.

The board then discusses whether other plans of improvement can be devised by which the probable demands of traffic, present and prospective, can be adequately met. A brief discussion of river transportation includes this statement:

Finished products seek rail transportation, and the only effect of navigable waterways upon their transportation is a possible reduction or control of freight rates. The existing improvement of the Mississippi River has had a marked effect on freight rates between St. Louis and New Orleans, reducing them nearly to those between St. Louis and New York. These latter rates have resulted from the influence of the Great Lakes and the Erie Canal on the competing Chicago rates, similarly the influence of the Mississippi River on southern rates from St. Louis affects those from Chicago south and but little reduction can be expected from a further deepening of the river.

The board also is of the opinion that the probable demands of traffic, present and prospective, for many years to come, can be adequately met by a channel of 9-foot depth between Chicago and Cairo, of dimensions similar to those proposed for the Ohio River.

The Board of Engineers for Rivers and Harbors, in its review of the special board's report, increases the estimate for construction by \$30,197,462 and the annual cost of maintenance by \$310,000. It does not appear to have procured any additional data as to the effect of a 14-foot channel upon the commerce of the Mississippi. It expresses the opinion that the present demands of commerce are adequately met by an 8-foot channel to Cairo and a 9-foot channel below Cairo, and that present and prospective commerce will be

adequately served by a 9-foot channel. The Chief of Engineers transmits these reports and expresses his agreement with the views of the Board of Engineers for Rivers and Harbors.

Appendix 20 of the board's report gives a study of the present and prospective commerce of the river from St. Louis to the Gulf, and a general study of the question of river and rail transportation. This study is long and difficult of condensation; it should be read in its entirety. A few extracts will serve to show, it is believed, the point of view from which it was written, *i. e.*, the present and prospective commerce of the river, and *not* the present and prospective benefit to the people of the United States of an improved river.

The appendix says:

There are six different points of inquiry to be specially investigated in any serious examination of the present and prospective commerce of any waterway, viz, (a) extent of population and of manufacturing, agricultural, and other business interests which call for water transportation; (b) the waterway itself, with its navigable channels, and especially their condition and capacity; (c) the boats, including their equipment and service; (d) the amount and character of the freights, either actually carried or demanding carriage; (e) the ports or other terminal points of load and discharge, including their harbors, piers, wharves, slips, docks, unloading and loading machinery, and other transfer facilities; and (f) the rail and water competition and their relative capacities, facilities, service, and freight rates.

“The past decrease of commerce and the lack of increase of commerce on these rivers is not due to lack of depth in the river. * * * In Germany * * * it is comparatively easy for them to keep their waterway full of steamers and barges. * * * As population and general business increase * * * the waterways will probably again resume their proper place as a valuable and economical method of freight transportation * * *.” The advantages and disadvantages of water transportation as compared to rail transportation are set forth, and a very brief statement made as to how a proper comparison of the final cost of shipment by boat and rail should be made.

PANAMA CANAL

The last of the four examples which have been chosen to illustrate methods followed in ascertaining or determining the value of a waterway improvement is the Report of the Isthmian Canal Commission dated November 16, 1901. Although the act of Congress under which this Commission was appointed does not instruct the President of the United States to ascertain the future value of an Isthmian Canal, the instructions of the President to the chairman

of the Canal Commission authorize "any line of inquiry * * * of interest or benefit." The Commission determined upon a division of subjects for investigation and each was referred to a separate committee. The subject pertinent to this article is "The Industrial, Commercial, and Military Value of an Interoceanic Canal," because such value must be ascertained before an opinion can be expressed upon the advisability of construction. It appears that the act of Congress does not instruct the President of the United States to express his opinion upon the advisability of the construction of an Isthmian Canal unless the following words appearing in the act are so construed: "To make a full and complete investigation of the Isthmus of Panama * * * to report to Congress the results of such investigations, together with his recommendations in the premises."

The Commission made an elaborate investigation upon the future value of an Isthmian Canal, which, with the appendix upon that subject, covers 234 pages of Senate Doc. No. 54, Fifty-seventh Congress, first session, reprinted in quarto form in 1904, forming a most complete study of the value of a waterway improvement.

The Canal Commission reports somewhat as follows:

An investigation of the Isthmian Canal from the standpoint of its use, aside from military considerations, has two phases—one industrial and the other commercial. A study of the resources and industries of the United States and the countries of the Pacific preceded and was used as the basis for the investigation of traffic and tolls, because a knowledge of industrial conditions is essential to an understanding of the effects which the canal will have, and to an analysis of statistical data concerning commerce. The general conclusions to which this inquiry has led are given without claiming that they are absolutely correct in every particular, but they are close approximations to the truth attained by careful research and furnish information necessary to a decision as to whether or not the canal should be constructed by the United States.

The canal will assist a wide range of industries, agricultural, mineral, lumbering, and manufacturing, and will promote the progress of all sections of the country. Cheaper transportation by an all-water route for the North Atlantic trade of the Pacific coast will be of great assistance to the development of that section. The canal will have an especially direct and important effect upon the market for American coal. Its effect upon the railroads in the eastern and southern sections of the United States will be favorable.

It will result in developing the industries and commerce of Pacific countries and increasing their trade. A study of the foreign commerce of the United States was made to ascertain the tonnage of vessels and cargo that might have passed through an interoceanic canal, and the probable growth of this tonnage in ten and twenty years. The subject of tolls was investigated and a reasonable charge determined. Each of the above statements is deduced from elaborate statistics and careful assumptions.

As a conclusion, it appears that a probable annual traffic of 7,000,000 tons in the year 1924, at \$1 per ton, will produce a revenue of \$7,000,000. The expenses of operation and maintenance are estimated at about \$2,000,000 per annum. The net revenue would not be sufficient, at the opening of the canal, to pay a rate of interest upon the capital invested which would compensate a corporation for the risks involved. It is the opinion of the Commission, however, that there are considerations more important than revenue. The revenue-producing function of the canal will be a minor one as compared with its services in promoting the industrial and commercial progress and general welfare of the United States.

As to the military value of an Isthmian Canal, the Commission, after some discussion of details, gives its opinion that—

A neutral canal, operated and controlled by American citizens, would materially add to the military strength of the United States; that a canal, whether neutral or not, controlled by foreigners, would be a source of weakness to the United States rather than of strength; and that a canal not neutral, to be defended by the United States, whether by fortifications on land or by the Navy at sea, would be a source of weakness.

An analysis of these reports might be made at this point from various points of view, but it seems advisable to omit discussion and state some of the general principles of transportation and its relation to waterway improvement, from which a point of view or basis for analysis may be established.

The word "transportation" signifies, as here used, the movement of persons, animals, or inanimate objects from one place to another. The object of the movement may be pleasure or profit, or both. We are concerned with transportation for profit.

The mere movement itself is non-productive, and is, in that sense, a loss, a waste, whether of time or labor, or both. Consequently, reduction in time or labor of transportation means a sav-

ing or a gain which can be measured, in almost every case, in money values—wealth.

On the other hand, the transportation of an article from a place where it has no value to a place where it has some value is a distinct gain to the owner of the article. Several articles may be brought to a place where they have a value when combined. In this sense, transportation is productive of wealth.

If all the articles necessary for life and comfort were produced in every locality, and if human beings desiring or needing those articles were uniformly distributed over the earth's surface, the need for transportation would be largely eliminated. The uneven distribution over the earth's surface of its population, its tillable soil, its minerals and other sources of production, calls for transportation, and much of the energy and time of the people is expended in paying for it. Lessening the cost of transportation means, therefore, a gain in wealth simply through a saving of time and labor.

Again, when various articles are brought from distant places to a common point, and by reason of cheap labor and cheap transportation can be manufactured into articles of usefulness, the wealth of the world is increased.

The discovery of a new and cheaper method of transportation, or diminishing cost of transportation by any means whatever, is a gain to the people of a nation. To the consumer, it means cheaper food and clothing, cheaper materials used in construction of dwellings, factories, etc.; it lessens the cost of manufacture, etc.; for the producer, it stimulates agriculture, mining, and manufactures, through increased ability to undersell in a competitive market; increased values follow from these effects. Cheaper transportation means lower prices, lower prices encourage greater consumption, and the latter causes greater transportation.

We must note the fact that increased facilities do not necessarily increase traffic, because rates may be such that property would not move; the market price of the commodity may not warrant the movement. There is a point somewhere to which property can not be transported without consuming its own value, the market price does not warrant transportation beyond a certain limit, illustrated by the movement of wheat, as shown in a following paragraph.

The effect of cheaper and quicker transportation upon governmental work of all descriptions needs no discussion; every governmental department will be benefited. The movement of mails and

Government property is an expense to the whole people. Especially important, however, is the movement of troops and war material, whether naval or military, in time of war. Rapid mobilization at the outbreak of war, and rapid movement during war, are chief elements of success, and some nations have constructed water and rail lines of transportation for these purposes alone. Our Government has therefore a special interest in its waterway improvement for National defense, and every improvement should be examined from this point of view.

A system or line of transportation includes a motive power, a conveyor (vessel, car, etc.) moved by the power, and a medium (channel or permanent way) on which the conveyor is moved from initial point to destination. The simplest system is pack animal and wagon, moving on natural or artificial roads. The merchandise to be transported for the shipper is loaded by simple means at one terminus and unloaded by the consignee at the other. If consignor and consignee are located at the termini of a water or rail system, the operation is equally simple, although the loading and unloading facilities become more elaborate. If two systems must be used, special transfer facilities are required. The cost of each operation involved in any shipment is readily determined, and the total cost depends not only upon the actual cost of moving the merchandise on each system, but the number and cost of transshipments. Cost of permanent way, interest on original cost, insurance (marine, accident, etc.), cost of operation and maintenance, are all elements of the entire cost of transportation. Because of cost of operation, wagon transportation can be a competitor of railways for comparatively short distances only. The relative cheapness of placing railway terminals at initial points gives that system an advantage over waterways, but admitting that the actual cost of transportation by a water line is cheaper than by a railway line, if water lines were capable of being extended in all directions, railways could not compete for traffic with them in the general case. Where time is an element, railways have advantages, but even in this case it can be shown that within certain limits water lines provide quicker delivery than rail lines.

In general, then, a shipment of merchandise from initial point to destination involves:

1. Loading on a slow and expensive conveyor;

2. Conveying to a storage depot located at the terminus of another system, for cheaper or more rapid transportation;
3. Loading on the new system;
4. Transportation by the new system;
5. Unloading at terminus of new system (reverse of No. 3);
6. Removing from terminal, by a third system, probably slower and more expensive than the second;
7. Unloading at destination.

The first and third systems may be animals, wagons, or electric lines; the second system may be rail or water. The introduction of other systems simply introduces new transshipments and conveyances.

Lessening the cost of any one of the seven operations lessens the total cost; hence the great value of cheap terminal and transfer facilities, a subject now engaging the minds of various officials in connection with water transportation. The operation of transfer from one vehicle to another is not only more or less expensive both in time and labor, but is, as a rule, detrimental to the value of the commodities—perishable fruits furnish probably the most notable examples. A transportation company or organization that performs all of the operations or which has a system reaching all shippers has a great advantage over other companies performing only one or two, provided, of course, that the total cost is less by the organized than by the unorganized means. In fact, by manipulation of rates it is possible for the single company to recoup its losses at competitive places by gains at non-competitive points. Hence the railroads of the United States, by combination, by furnishing storage warehouses, terminal facilities, and branch lines to points of origin, have been enabled to drive out of business competing water lines, which usually furnish none of these things.

The predominating importance of through traffic in modern industrial and commercial conditions makes this lack of unity in our waterways and lines of water transportation a most serious defect, and accounts to a great degree for their failure to hold their own in competition with rail systems.

These apparently simple statements about transportation are, when carried out in detail, very complex. It is unnecessary to offer proofs of them. They find an application in this case in showing that a waterway is an element of a transportation line, and one element only, and that the improvement of a waterway must be ex-

amined in its relation to each and all of the other operations involved in a shipment of merchandise from origin to destination. The result which flows from improving a waterway is cheaper transportation, and cheaper transportation brings about all the other effects previously enumerated.

As an example of the influence of an expensive haul upon the movement of traffic, the situation at Dover, N. H., may be cited. At this place the freight rates on coal from Portsmouth, N. H., are the same by rail and water; hence the manufacturing establishments along the river bank receive their coal by water, while those at a distance have it shipped by rail to avoid wagon delivery.

It is a curious fact that in 1872 the establishment of adequate terminal facilities at the chief exporting ports was advanced as an effective means of cheapening the cost of transport by rail, whereas at the present time the same idea is advanced as a means of cheapening water transportation.

It would be interesting at this point to study the development and growth of systems of transportation throughout the world, but a brief statement covering the United States is sufficient. The early settlement of the country was invariably along a water front, whether ocean, river, or lake. The growth of population required extension into the interior and the connection of populated centers by wagon road, canal, and improvement of rivers to fit the known methods of transportation. Turnpike roads and canals covering the country east of the Mississippi were planned as shown in the Gallatin Report of 1808. Robert Fulton took great pains to show the great value of canals in cheapening transportation. Then came the invention of the railway and its growth into great systems. The wagon road was eliminated as a long-distance system. The canal and railroad came into competition, the railway systems combined, trade grew to colossal proportions and abuses grew up, against which complaint was made, as well as against the insufficient facilities provided by the railways for handling the traffic. The improvement of waterways and the construction of additional channels of communication had been wholly inadequate to meet the growing demands of trade, and by reason of this neglect the commerce of the country had been compelled to accept the more expensive methods afforded by railroads, at the period when the Senate Committee on Transportation Routes to the Seaboard investigated the questions assigned to it.

The effect of cheaper transportation had been to open to settle-

ment the west and northwest, and to make them productive regions, eventually resulting in the great commerce above referred to. The inevitable competition between rival systems had occurred, and still continues between rail and water. New inventions may bring the turnpike again into the lists, and even the atmosphere may become a competitor for commerce.

An excellent example of the influence of cheaper transportation upon the industries of the country, among a number of others, is given in an article entitled, "Why is a freight rate?" published in a recent number of the *Saturday Evening Post*. The writer says:

Several years ago there were comparatively few oranges produced in southern California. In order to develop the industry it was necessary to place the product on the market along the Atlantic seaboard in competition with imported fruit. Gradually the traffic experts developed the idea of making a flat rate on California citrus fruits to all territory east of the Rocky Mountains. This rate was made just as high as it could be and still allow the California grower to meet foreign competition and make a profit. Competition could not reach the interior as readily as it could the Atlantic seaboard, and, therefore, the same rate could be charged to Omaha as to New York. While the New York rate was, perhaps, low, the rate to western points yielded so great a profit that the railroads more than played even. That is why it costs no more to ship a car of oranges from Los Angeles to Boston than to Kansas City.

This rate plan greatly widened the market for southern California oranges, and it built up the industry until that region now grows 80 per cent of all the oranges consumed in the United States. The industry yields a revenue to the railroads of more than \$10,000,000 a year on 30,000 cars shipped. This year the shipments will reach above 36,000 cars. Besides, the industry has created a demand for eastern goods out there.

The Senate Committee on Transportation Routes to the Seaboard investigated the annual average price of wheat and corn from 1868 to 1872 at various cities; the quantity of grain received and shipped from ports on the lakes, the Ohio and Mississippi rivers, and the Atlantic and Gulf coasts; the quantity shipped by various routes; the average annual freight charges between various terminal points; the prices of grain in English markets, and the sources from whence it came. Other subjects investigated were: combinations and consolidations of freight lines, "stock-watering," competition between railroads and water-lines, the relative cost of the various methods of transportation, the governmental regulation of railroads, the construction of governmental railroads, etc. One of the most important branches of the committee's work was that of the improvement and construction of water-lines of transport. The list of subjects shows how exhaustive was the investi-

gation, and although the report is now thirty-five years old and the industrial and commercial conditions have changed greatly, it might have been written yesterday, so far as questions of transportation alone are concerned. The movement of trade was the same as now; the great trunk lines had been formed, high freight rates and discrimination among shippers existed, competition resulted in new lines and combination among old lines, competition between rail and water lines had resulted in the establishment of steamer lines by the railway companies and special rates to competitive points, and it was recognized that water routes are the surest competitors and the only effective regulators of railroads. It was also established that Congress could legally not only provide waterways for transportation, and regulate the movement of traffic by rail, but could also construct and operate railways. The investigations of the committee led to the conclusion that the practical and substantial relief demanded by the public is to be found only in a Government freight railway, or in the improvement and construction of water channels, and it therefore recommends, as the obvious and certain solution of the problem of *cheap* transportation, that four channels of commerce be created or improved: First, the Mississippi River; second, from the Mississippi River to New York City via the Northern Lakes; third, from the Mississippi via the Ohio and Kanawha rivers to tide water in Virginia; fourth, from the Mississippi via the Ohio and Tennessee to a point in Alabama or Tennessee and thence by canal and slack water or by a freight railway to the ocean. The estimated cost of these routes and the benefits to be derived from them in saving on freight rates are carefully calculated. The stimulation to production, the enhancement in value of farm lands, the increase in foreign commerce, are also estimated.

The Senate committee also believed that, to secure and maintain cheap transportation, competition is essential in two particulars, it must be controlled by a power with which combination is impossible, and it must operate through cheaper and more ample channels of commerce than were then provided. Railway competition invariably ends in combination, whether with rail or water lines. The results of competition between railways owned by private corporations and between this class of railways and government-owned railways is shown by experience in Europe. The example of Belgium in 1872 shows that eventually the best interests of the people

were served by an agreement between the government and the private companies as to rail rates.

In order to maintain in the United States a form of competition between rail, water, and rail and water routes, it is necessary to provide for through bills of lading and prorating, and for common terminals. Whether the Government should provide these common facilities is open to discussion, but it is not proposed here to consider the subject of Government ownership of transportation lines, since present methods of river and harbor improvement by the United States do not involve the subject.

An interesting statement is given in the report of the Senate committee showing the value of a ton of wheat and one of corn at a given distance from market, as affected by cost of transportation, respectively, by canal, by railroad, and over the ordinary highway. At 330 miles the cost of carriage on common roads consumes the whole value of wheat, leaving nothing for the farmer. At 3,300 miles the railway sweeps off the total value, but on canals the value is not wholly exhausted within a distance of 9,900 miles.

A few examples showing the effect of improved waterways will fix in the mind the views so fully developed by the Senate committee's report.

The Erie Canal was originally constructed for boats of 76 tons, but the development of commerce surpassed the anticipations of its projectors, and a demand for cheaper transportation resulted in its enlargement in 1862 for boats of 240 tons. The financial result of the construction of the canal up to 1867 was a net profit over all expenses of about \$41,400,000. This amount, and more, was, however, absorbed by the construction of lateral canals. The financial results were small, however, compared with the commercial results in developing the western and northwestern States and in placing New York in the first rank among the States of the Union. The immediate result of the enlargement of the canal in 1862 was the reduction in cost of transport of 50 per cent.

The Fox River (Wisconsin) is reported for many years as having an effect upon rates and upon all freight movements to and from points in the Fox River valley, which is the most thickly settled portion of the interior of Wisconsin and an important manufacturing region. All freight rates during the season of navigation, and particularly of heavy freight, are reduced to near the price of water carriage, whether carried by boat or by competing railroads. The same thing may be said of all waterways, for an

examination of railroad freight tariffs (local and transcontinental) shows that from Eastport, Me., to the Ohio Valley and the Pacific coast, ocean, gulf and river ports have a lower rate than inland points but a few miles away.

The effect of constructing wharves at the railroad terminal at Stockton Harbor, Me., and the favorable report upon the improvement of the harbor by the United States, is said to have enabled the Bangor and Aroostook Railroad, which reaches many points in northern Maine, to make favorable arrangements for the transfer of cars to and from connecting lines, and to have been marked by an increase of 50 per cent in joint rail traffic.

It has been invariably seen that, in the past, the improvement of a waterway increases traffic upon parallel and competing railway lines.

Many examples can be found to show that the improvement or construction of a waterway leading to a center of population or manufacture has resulted in an enormous increase in its commerce. Nantes and Manchester are examples. The growth of commerce on the Kiel Canal, constructed for purely military purposes, is worthy of note.

It has been now shown that river and harbor acts directing examinations or surveys of certain waterways may be interpreted to mean that Congress desires a report upon advisability of improvement in its broadest sense, with the facts and reasons upon which an opinion is based, fully and particularly stated. A few examples have been given showing the methods followed by various officers in reaching an opinion upon the advisability of improvement in particular cases. A few of the general principles governing the movement of merchandise have been given, as well as a number of examples illustrating the effects of cheapening transportation by rail and water routes. The relation of railways and waterways has been touched on, to show that they both form parts of the general subject of transportation.

It now remains to develop, if possible, a system or method, by following which the determination of the advisability of a waterway improvement will become more of a matter of balancing facts than beliefs. By advisability is understood: proper to be done, expedient, most practicable or best to be done, all things being considered. Expediency implies opinion, but correct opinion rests upon proper deduction from knowledge, and a deduction is a proposition necessarily true when the premises and processes are true.

Let us, then, ascertain what are the premises of waterway improvement, and arrange them into a system, if possible, covering all cases. The logical conclusion upon advisability should readily follow in any given case.

In an official report upon the appropriations and expenditures for river and harbor improvement from the beginning of the Government to the year 1883, the following opinions are expressed by the Chief of Engineers:

With respect to "the benefit to commerce that has resulted from each expenditure," it should be remarked that, although an increase of the depth of a harbor or its approaches, or the opening of a river to navigation, or the permanent increase of its depth are benefits to commerce by creating greater facilities for navigation, the extent of this benefit is not readily ascertained. It can not invariably be found by a comparison of the commercial statistics of late years with those of a former period taken from the reports of the officers in charge of the improvement, because there is no reliable source from which these statistics can always be obtained by them, and that they are frequently estimates of interested parties. Nor does it follow that unless there has been an increase of commerce the benefit resulting from the improvement has been of little value, since an increase or diminution of commerce may arise from local causes entirely independent of the facilities afforded to navigation by the improvement itself. A comparison of the money value of the trade at different dates does not always indicate the relative benefit to commerce for the same reason. Nor does a comparison of the number of vessels trading at a port or on a river invariably indicate the comparative amount of commerce, since an increase of the depth obtained by improvement enables the employment of vessels of a larger class, and although trade may have become greater, the number of vessels engaged in it may be less.

The Chief of Engineers expresses no opinion as to whether benefit to commerce may be ascertained by comparison of other things than water-borne commerce.

Going further back in time, we find a board of Engineer officers in 1874 expressing the opinions that, concerning the benefit to commerce to be derived from the construction of a certain proposed work, the board can only speak in general terms; indeed, it could not be expected of its members, most of whom are little conversant with the statistics of commerce and with those intricate details which are involved in questions merely of profit on capital invested, to speak otherwise than in general terms; in such terms the unanimous opinion of the board is expressed in the following language: "This route presents extraordinary claims as the measure of relief to the population of the Western States, in furnishing them for their bulky productions cheap transportation to a market, and for

fostering the commerce of the United States by developing immense mineral resources now neglected."

The language employed in the acts of Congress directing the examinations of the Connecticut River, the Ohio and Mississippi rivers, and the Panama Canal, is not the same in each case, but there is sufficient similarity to show that the purpose of Congress was to secure not only an expression of opinion from the boards of officers charged with the duty of making the examinations, but also all data pertinent to a full and satisfactory consideration of the proposed improvement.

These examples, as well as others, show also much diversity of opinion among officers as to what facts constitute the elements affecting advisability. In some cases only present commerce on the waterway is given; in others an effort is made to estimate the future commerce. Railroad traffic statistics are given in some cases, and again an estimate is made to determine from the total output of manufactured products in the vicinity of the waterway the amount of freight which will be transported on the improved waterway. A comparison of rates is then made and the saving computed upon the prospective commerce. It appears that the guiding thought in the minds of those who made the reports and examinations was to ascertain the present commerce on the waterway, to estimate the future commerce on the waterway, and from a comparison of rail and water rates to form an opinion as to the advisability of improvement. The guiding thought was transportation by water. If an error is made in thus assuming the guiding thought, it arises from the apparent meagerness of the reports. Perhaps the writers of the reports did not deem it advisable or necessary to include all the facts or circumstances of the case before them. Yet Congress has expressly asked for these facts and reasons. Many persons have expressed the thought that the value of a waterway is shown only by the number of vessels making use of it.

A recent article on "The Waterways of the United States: Actual Expenditures and Results to Navigation and Commerce" shows, by careful compilation and comparison, the total expenditures, original and present depths, and original and present commerce upon the 495 works upon which the Government is now engaged. It appears that the annual cost per ton to the United States of all water-borne commerce is 6 cents. The writer says: "It would be interesting to know what saving this 6-cent expenditure has ef-

feeted. Any estimate would be little more than a guess and could not be verified." After discussing the decline of water transportation, the writer says: "It is not a matter of surprise that in the general development and building up of our country some of the early established routes should show a decline of commerce in favor of others more advantageously located."

On the other hand, we meet many expressions in official reports showing the belief of the writers that present and prospective commerce are not the only elements in the value of a waterway, but that another important element is its influence upon railway freight rates. A measure of the advantage to be derived from a waterway is given by one writer as the difference between existing rates and what would be demanded were there no water competition. In parenthesis it may be said that this measure would be very difficult to apply.

Advisability can be determined only by contrasting advantages and disadvantages, receipts, and expenditures. No new enterprise is inaugurated until income and outlay have been calculated. The advantage of a waterway improvement can only arise from it as a cheaper line of transportation, the disadvantage is its relative cost; our problem has therefore the twofold aspect of a transportation problem and an engineering problem. Since the law requires that the Engineer officer charged with an examination or survey shall report upon the advisability of the proposed improvement, no argument is needed to prove that he must familiarize himself with both engineering and transportation. There are many printed volumes on the subject of engineering, but none cover both engineering and transportation.

We are concerned here with engineering only so far as it bears a relation to advisability, and this relation in general terms is expressed by the word cost, which for convenience is divided into cost of original construction, cost of maintenance and operation, and interest on original cost.

The question, What shall be done by the General Government in the way of establishing or providing terminal and transfer facilities for the handling of passengers and merchandise and of developing and utilizing water power for industrial and commercial purposes? is limited, in the act of March 3, 1909, to consideration only so far as they have a "bearing upon the improvement of navigation and to the possibility and desirability of their being co-ordinated in a logical and proper manner with improvements for navi-

gation to lessen the cost of such improvements and to compensate the Government for expenditures made in the interest of navigation." This limitation seems to make it unnecessary, except as an element of cost, to include in this discussion terminals and water powers. The general policy of the advisability of providing terminal facilities and water powers in connection with transportation by water does not seem to have been submitted heretofore to the War Department. The State of New York, it appears, believes that adequate terminals are a part of the Barge Canal improvement, although sentiment up to this time is divided as to what form these facilities shall take.

A waterway, as a transportation line, may form part of a through water line, or connect with a line of railway as part of a through or local line of transportation. Natural waterways are unfortunately fixed in direction and can not form parts of through lines unless their direction coincides more or less with the general direction of the other parts of the through line, although this disadvantage may sometimes be overcome by artificial channels connecting several waterways. It may be asserted here with propriety that a waterway improvement possesses National interest in its value to the public, and that the total saving to the public resulting from its construction, whether on water or rail rates, is a measure of its value, whether the waterway carries more or less freight, or none at all, after improvement.

Past experience has shown that an unremunerative water line will eventually be abandoned by its owner; hence, to prevent the abandonment of water lines competing unsuccessfully with parallel or adjacent rail lines having lower freight rates or other advantages, something must be done by shippers or by the Government to limit competition or to provide the water line with advantages in other directions. Shippers have in some cases divided their freight shipments, when each of the two systems may have a superiority over the other at different seasons of the year. In those countries where government owns both rail and water routes, rates are readily fixed to accomplish the same purpose; that is, a diversion of shipments and the maintenance of both rail and water routes. The question of competition between different methods of transportation is interesting, but the scope of the article makes it unnecessary to discuss it further.

As a transportation problem, a waterway improvement is con-

cerned first with cost of operation and maintenance of the means used for transportation, including cost of various types of vessels, relative cost of operating the different types, speed or time of transit, marine insurance, terminal charges, through bills of lading, taxation, etc., and the relation of this cost to similar charges by rail or other means of transportation. By calculating these elements it may be readily determined whether the proposed waterway will affect beneficially local and through freight rates. Should lower rates be made possible by an improved waterway, we may seek for those other results which flow from cheaper transportation. These results, already referred to, are increased agricultural and mineral production, increased manufactures, increased land values, and in their turn larger shipments by all means of transportation. To calculate these remote effects of an improved waterway is difficult, but it would seem to be possible, by a careful study of natural resources and labor conditions, to forecast advantage or disadvantage.

The problem may perhaps be simplified by classifying waterways. Classification may be made from various points of view; one method is used in Part I of the Report of the Commissioner of Corporations on Transportation by Water in the United States; another method is employed in the article previously referred to on "The Waterways of the United States: Actual Expenditures and Results to Navigation and Commerce," found in No. 18, Vol. LXI, Engineering News. These classifications are interesting, but of no assistance in determining advisability of waterway improvement. For this specific purpose waterways may be classified from the point of view of their relation to transportation into: (1), channels for the passage of vessels; (2), areas for the anchorage of vessels awaiting cargo or opportunity to discharge; (3), areas for the anchorage of vessels seeking shelter from storms, floods, ice, etc.

The first class includes rivers, canals, channels at harbor entrances, channels in harbors, etc., and require such engineering works of improvement as dredging, locks and dams, regularization, jetties, breakwaters, etc.

The second class includes natural or artificial areas, usually within harbors, or in wide portions of channels, and require dredging, breakwaters, etc.

The third class are harbors of refuge, properly so called; ice harbors and natural harbors. A sheltered basin of any sort may be-

come a harbor of refuge. The engineering works usually required are dredging and breakwaters.

HARBORS OF REFUGE

Taking up these classes in a reverse order, we are impressed with the fact that it will be very difficult to determine the effect upon a line of transportation of a harbor of refuge, whether located at a terminus, or some intermediate point of the line. Such a harbor may never be needed, yet if marine insurance on certain lines of water transportation is greater than on others, it is evident that marine risk is greater. Annual marine losses at special places would show at least the desirability of harbors of refuge near those places. Whether marine insurance would cost less on certain water routes by reason of the presence of a harbor of refuge could no doubt be ascertained in any special case from marine insurance companies. The elements of the problem of advisability, then, are beside the engineering cost, the number and value of vessels and cargoes passing the dangerous point, the annual number and value of crews and vessels lost near that point, the cost of marine insurance on lines of transportation passing that point, the probable reduction in marine insurance and freight rates on the lines due to the presence of a harbor of refuge, and the increase which may be expected in commerce and in agriculture, mineral, and manufactured products due to diminished freight rates.

ANCHORAGE GROUNDS

An anchorage basin should be conveniently accessible from the terminus of a water transportation line (a terminus being any point of shipment); it corresponds to the freight yards and sidings of railway systems. It is not much easier to determine the value of an anchorage basin than of a harbor of refuge. Anchorage grounds may or may not be necessary, depending upon the wharf frontage, terminal facilities, and maximum number of waiting vessels. Should the terminal facilities be insufficient to load and unload vessels as fast as they arrive, they must anchor somewhere and await their turn. A crowded condition at any terminus will soon be felt in freight rates, and if the available natural anchorage grounds are insufficient, artificial areas must be provided for present and future shipping. Moreover, every commercial harbor may at times be used as a harbor of refuge. The elements entering the problem of advisability in this case are: cost of providing an-

chorage basins of various sizes to meet the demands of present and prospective shipping, number and size of vessels arriving and departing, annual tonnage, terminal facilities, gain to shippers in reduced freight rates by eliminating delays, and probable growth of business due to lower freight rates. A comparison of these elements should make it possible to form a fairly exact conclusion as to advisability.

CHANNELS

A channel may form a transportation line or part of such line. The transportation line may connect an ocean, lake, gulf, or river port with another of the same class, or it may unite all classes of ports. Its various parts may require the use of various types of vessels and of points of transshipment from one type to another. A channel may connect at its terminus with a local, through, or transcontinental railway line, or there may be no railway line. In most cases it will form with one or more railway lines a through line of transportation between certain points, and with others a competing line. Where its terminus has no railway line, the water line will compete with wagon transportation, or, in fact, perhaps provide transportation facilities where none exist, as in the case of an island.

To improve a channel, it may need to be widened, deepened, or straightened, thus eliminating currents or other dangers, resulting in greater ease and safety to navigation, and the possibility of using larger and speedier vessels; in other words, cheapening transportation between terminals, and bringing about all the other results which flow from cheaper transportation.

Improving the channel of an ocean, gulf, or lake harbor will result in increased exports, imports, and coastwise trade, indirectly benefiting connecting railways. Improving a channel leading to an inland terminus may make of it an ocean terminus, or if the channel lies between two inland termini it will cheapen rates on local and through freights moving in its general direction. To determine the advisability of improving a channel may, therefore, become a much more complex and difficult case than that of harbors of refuge and anchorage grounds.

The cost of channel improvement which will bring about, upon a certain water line, a definite reduction in freight rates between its termini is susceptible of calculation, and if the benefits of cheaper transportation are calculable, a project might be adopted whose

cost would equal the benefits. However, Congress has, as a rule, decided upon the place and extent of improvement and has required an opinion upon its advisability. The cost of the project may generally be calculated with a reasonable degree of exactness. We must then determine the value of that particular project as part of a transportation line. While it is safe to assume that an improved channel will lower the rate of transportation on present commerce, it is necessary to know also its effect upon the movement of all merchandise between its termini and the termini of connecting and competing systems of transportation, as well as its effect in developing the resources and manufactures of tributary territory.

We must ascertain the amount of present commerce, present freight rates (cost of transportation), conditions existing at any and all terminals, railway connections, if any, and methods of prorating, character, classes, and amount of all productions in the region tributary to the waterway as a local and through line of transportation, demand for raw materials and manufactured products, through and local freight rates upon various classes of merchandise on lines of transportation of which the waterway forms a part, cost of transportation on the improved waterway, annual traffic capacity of the improved waterway, time of transit of vessels, etc. All of these must be carefully examined to determine the value of a waterway. Some cases will be simple, such as an island or a harbor without railway competition, but, on the whole, no channel can be improved without upsetting the present balance in local and through freight rates. It would seem not to be impossible to calculate these elements with a fair degree of accuracy and thus form a correct opinion as to the advisability of a particular channel improvement.

Many examples may perhaps be found where the examinations and surveys have been conducted with a thorough understanding of the principles governing engineering and transportation, and correct conclusions as to advisability have been reached. The Senate Committee on Transportation Routes to the Seaboard presented a voluminous report, and advised the construction of certain waterways, none of which have been completed. The Isthmian Canal Commission investigated every element in advisability, but the accuracy of their conclusions has been challenged in many particulars.

The interest of the public in a canal across Cape Cod, shortening the route of all vessels passing from New York and points farther south, to Boston and other eastern points of the coast, is plainly evident. It shortens these routes by 65 miles and eliminates the dangers peculiar to the Cape Cod coast. A private corporation has undertaken the construction of this canal, and surely it must have done so only after investigating its advisability and reaching the conclusion that it would be profitable. A popular article has recently given a statement of the expected outlay and income, which included cost of construction, number of vessels on that line of transportation, probable saving to vessels and reasonable tolls for the use of the canal. Should the anticipations of the projectors be realized, and the correctness of their processes of investigation be thus established, we will have an example of a private corporation profiting from a waterway improvement which, if included in a river and harbor bill and submitted to the same method of examination must have resulted in a favorable opinion upon its advisability.

The elements entering into the problem of advisability may be summarized from the above discussion as follows, and they should be investigated in the order named. The first eight establish the transportation value of the improvement, the last three determine its engineering cost. Could they be calculated with any reasonable degree of accuracy in terms of the same unit of measure, advisability would be a simple sum in arithmetic. On the other hand, an almost infinite series of results follow waterway improvement, which the human mind has not yet shown itself wise enough to forecast.

(1) Present commerce by water, rail, or other means of transportation.

(2) Present condition with reference to production in agriculture, mining, and manufacture.

(3) Present systems of transportation, including a description of methods used, and terminal facilities.

(4) Cost of transportation as measured in freight rates by all systems for various classes of merchandise between all points which may be affected by the improvement.

(5) Effect of the improvement upon cost and rates of transportation, by water, rail, and other methods.

- (6) Effect upon present commerce and conditions mentioned under (1) and (2).
- (7) Possible further future effects under new conditions.
- (8) Effect upon National defense.
- (9) Cost of original construction.
- (10) Cost of operation and maintenance.
- (11) Annual interest upon original cost.

These are the rules. Their application rests with the officer, and must be adapted to meet local conditions.

It would be interesting to discuss the decline of water transportation in the United States as a related subject. It is pertinent to remark only that a recognition of the great value of water transportation has caused railways to parallel water lines, to establish their own vessel lines, to acquire water front property and terminals for their own use, as well as to destroy their competitors. Because of present conditions perhaps the minds of many men have become confused as to the relative value of rail and water transportation.

It would also be interesting to discuss the question: Assuming that the United States has to-day acquired possession of all lines of transportation within its boundaries, and proposes to operate them for the benefit of all sections of the country, what changes in freight rates would be made, and what new rail and water lines of transportation would be opened? The question of determining the advisability of a waterway under such circumstances would be no less complicated than under present conditions, but the answer would probably be very different.

The writer had intended to close this paper at this point, but ideas continue to force themselves upon the attention, to be weighed, discussed, and laid aside as not coming within the limits of the title. One can not fail to be impressed with the importance of a study of the whole transportation subject. A correct understanding of water transportation demands a knowledge of land transportation, and both are absolutely necessary to the proper equipment of any body of men from whom the public has a right to expect expert advice and wise action. The nation is advancing; more is expected, and more demanded. The great land transportation systems are being developed and made successful through the combined efforts of energetic and capable men. The transportation business is organized into great departments, individuals are

selected for their control, given great powers of initiative, held responsible for results, and rewarded for successes. Would it be reasonable in a great private business to expect that all improvements should be suggested by the head of the establishment, and that the heads of the departments should be content with a strict compliance with orders and with no interest beyond, nor study for betterment. Such a concern would be speedily left behind. Applying this principle to our work in connection with waterway improvements, how well would we find ourselves prepared should the present method of conducting preliminary examinations be reversed? Suppose that Congress should direct that each officer should be held responsible for the waterways in his district, that he should be required annually or otherwise to report concerning its commercial needs somewhat as a division superintendent of a railroad is held responsible for the operation and conditions of his division; assume that the officer was empowered and directed to keep himself currently informed as to his district; in other words, that he has a standing order for a preliminary examination of his district, reporting its needs from time to time, for action by Congress as it may deem best in making appropriations for surveys and improvements, what effect would this have upon public interests?

The district engineer officer is now the custodian of the needs of his district so far as concerns the removal of wrecks, obstructions to navigation, construction of wharves, bridges, fish weirs, occupation of public works, enforcement of rules and regulations governing the use of navigable waterways and the advisability of improving special localities. From time to time special allotments of funds are made to carry on the work necessitated by the above duties. If he were also charged with the duty of supervising the needs of his district for additional facilities for water transportation, would this not be simply an enlargement of these duties?

Under these enlarged powers he would make a preliminary examination of his entire district by the same methods and upon the same lines as have been advocated in this paper for a particular waterway improvement. He would study agriculture, mineral, industrial, and commercial conditions, lines of transportation, terminal facilities, freight rates, insurance rates, wharfage charges, physical conditions of the waterways, etc. Are we or are we not sufficiently instructed to discharge this duty? Or must this work be left in other hands?

THE EMERGENCY GATES OF THE ILLINOIS AND MISSISSIPPI CANAL

BY

MAJOR C. S. RICÉ
Corps of Engineers

The Illinois and Mississippi Canal, popularly known as the Hennepin Canal, connects the Upper Illinois River, near Hennepin and Bureau Junction, with the Upper Mississippi at the mouth of Rock River, just below Rock Island, Ill.

The main line of this canal is 75 miles long from river to river. It rises from the Illinois 196 feet in 18 miles to its summit level and descends 93 feet in 46 miles from its summit to the Mississippi. The summit level is 11 miles in length.

This summit is supplied with water from Rock River, near Sterling, Ill., by a navigable feeder 29.3 miles long, which connects with the summit level near its western end.

There is a guard lock at the head of the feeder where it leaves Rock River, but from there to either end of the summit level of the canal there is no lock, and feeder and summit level combined form some 40.3 miles of unbroken canal, containing when completely filled some 100,000,000 cubic feet of water.

A break or crevasse in any part of this 40.3 miles would allow practically all of this water to escape into the surrounding country. The necessity was felt of minimizing the damage that would occur in case of a break by providing gates which could be closed quickly in case of an emergency of this nature, thus reducing the amount of water that would escape.

Twenty-three miles below its head, at Rock River, the feeder by an aqueduct crosses a small stream known as Green River. This aqueduct being practically in the middle of the long stretch of combined feeder and summit level, it was believed that such gates should be located there. It would then be possible to reduce by half the amount of water that could escape in case of a crevasse. The

abutments of the aqueduct offered an opportunity for a suitable foundation for such gates at small additional expense.

The canal when full of water is 7 feet deep. Its surface is then about 16 feet above the surface of Green River, beneath the aqueduct, when the river is at its ordinary stage. There was thus ample head of water for any device that might be adopted for maneuvering gates of this character.

From the nature of the case any gates that might be selected should be of a kind that could be operated in the face of a stiff current of water. A crevasse north of the aqueduct would cause an immediate rush of water to the north, while one south would cause a rush of water southward. The gates would have to be operated in this current. Manifestly, mitering gates of the ordinary type would not answer.

The gate finally adopted was suggested by Mr. Chr. Holth, the engineer in charge of the designing work in the headquarters office in Chicago. The detailed design and drawings of the gate were made by Mr. Fred W. Honens, under the immediate supervision of Assistant Engineer L. L. Wheeler.

It is a simple form of the Des Fontaines type of weir, the details of which can be seen in the accompanying drawings and photographs.

Briefly, the gate is formed of a series of parallel I-beams, each of which is hinged to the supporting masonry, close to its middle point, and all of which are connected by a metal skin, to which they are riveted.

Normally, the gate lies horizontal at the bottom of the aqueduct, metal skin on top and hinges below.

The hinges are close to the median line of the gate, dividing it into two parts.

Under one of these parts there is a chamber or trench in the masonry, into which this part of the gate can swing, the other part rising and forming a dam across the aqueduct, the gate moving on its hinges like and ordinary seesaw.

The part of the gate that swings down into the trench does not fit the masonry closely at its swinging edge, but this edge is provided with a hinged mud guard or flap that keeps contact with the masonry as the gate swings.

The part of the gate on the opposite side of the hinges from the trench is somewhat the larger and heavier, and provision is made

for adding weight in the shape of railroad iron, etc., to insure proper operation.

When the water in the trench or chamber under the gate is at the same head as the water in the canal above the gate, the preponderance of weight in the heavier part will keep it lying flat upon the bottom of the aqueduct.

When by the proper manipulation of the valves the water in the trench under the gate is allowed to run out into the river below, the pressure on the part of the gate over this trench forces this part down and so raises the other part and dams the canal.

By the reverse manipulation of valves water is admitted from

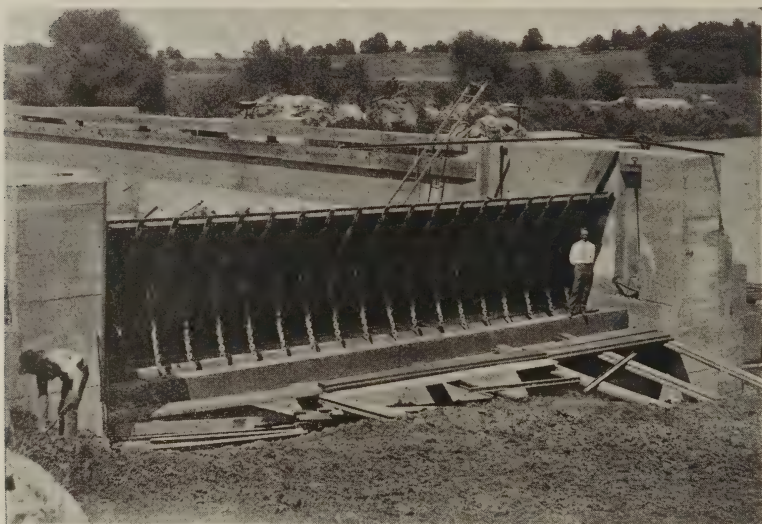


Fig. 2. Gate raised, showing safety chains and counterweight hooks.

the canal into the trench, and the gate slowly drops to its horizontal position by the action of gravity.

It was intended that the gate should be so operated that it would rise *against* any current that might develop in the canal, in order that it might come into position gently and without shock, and so avoid danger of being carried away, as was feared might be the case were it to be raised *with* the current.

Two gates were therefore provided, one at each end of the aqueduct; the one at the south end to be operated against the southerly current that would be caused by a crevasse south of the aqueduct, and the other at the north end to be operated against a northerly

current that would be caused by a crevasse north of the aqueduct.

But as one of the gates might, either accidentally or purposely, be operated in the reverse direction, and have to rise with the current instead of against it, additional precautions against its being carried away were taken by providing chains connecting each I-beam in the heavier part of the gate to an anchor in the masonry below.

The gates rising with the current would thus be stopped and held by these chains and by the central hinges.

At each side of the aqueduct the gate works with a clearance of approximately 1 inch between itself and the masonry, and when



Fig. 3. Emergency gate in normal position flush with aqueduct floor.

raised presses against a wooden cushion, forming a nearly tight dam across the canal.

After these gates had been installed and the canal filled with water, there was no opportunity to test them for the emergency use for which they were intended. They could be raised and lowered as desired in the comparatively still water of the canal. How they would operate in the face of a strong current remained to be seen.

The test finally came after the gates had been in place and under water for about a year and a half. During the night of May 16-17, 1909, a crevasse occurred immediately at the southeast corner of the aqueduct.

It is thought that this crevasse started about 3 a. m. The alarm was given about 5 a. m., and the overseer, who lived about a quarter mile from the aqueduct, hurried to it and found that the gate at the *north* end of the aqueduct had been automatically raised by the current and was holding in the canal all water north of the aqueduct.

The crevasse was repaired in due course, and water had again been admitted to all parts of the canal when a second crevasse occurred at the same spot, the southeast corner of the aqueduct.

This time it was daylight, and Overseer W. H. Murphy happened to be present. What occurred can best be told in his own words:

About 7 p. m. I examined the river bed near the south abutment and saw nothing unusual. At 7.45 p. m., the exact time of the break, I was standing with the night watchman on a sand bar a few feet east of the east end of the north pier, about 140 feet from the southeast corner of the aqueduct, looking toward the spot where the break occurred. At first, a stream of black water about 10 inches in diameter and 18 inches high shot up at a point about 8 feet east and 10 feet north of the northeast corner of the south abutment.

We ran immediately to the southeast corner of the aqueduct to close the south emergency gate. By the time we got there the water was running very swiftly over the gate and the gate would not close when the valve was opened. We then ran to the north gate and closed it. The north gate closed easily and quickly, but without any shock.

While trying to close the south gate I saw about 25 feet of the crib over the break go out. Part of the stone in the crib fell through and the timbers in the crib broke.

The crib was carried about 200 feet to the north side of the river and the stone was scattered all the way across.

The upper part of the east embankment south of the aqueduct held until after we closed the north emergency gate, the water having made a tunnel at the bottom. The first of the top fell in about 12 or 14 feet south of the masonry, leaving the bank projecting about 3 feet.

I happened to have my watch in my hand when we first saw the break and looked at it again when the top of the bank fell in eight minutes later.

The crevasse occurring right at the south end of the aqueduct caused a practically torrential flow of water over the south gate. The current was too strong and the gate could not be raised against it. Had the crevasse been half a mile or more southward, it is probable that the current caused by it would not have been so strong as to prevent the gate's operation. But this yet remains to be seen.

There was no doubt, however, as to the north gate. It operated promptly, rising with the current and coming into place without

EMERGENCY GATE.
GREEN RIVER AQUEDUCT-NO. 9-FEEDER
ILLINOIS & MISSISSIPPI CANAL

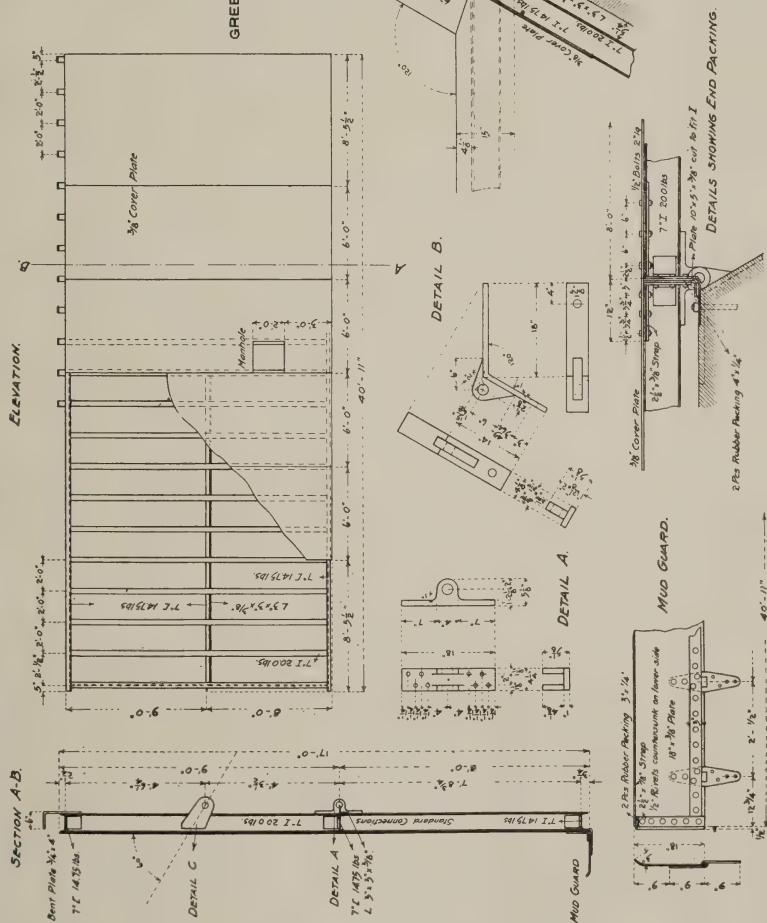


Fig. 4. Details of Green River emergency gate.

MAJOR C. S. BICHÉ, CORPS OF ENGINEERS, U.S.A., IN CHARGE.

Drawn by Fred W. Harnett, March 7, 1934.

Prepared under the direction of L. E. WHEELER, ASSISTANT U.S. ENGINEER.

shock, probably by reason of the cushioning effect of the water in the trench beneath it.

That this gate would have operated automatically is known, because it did so operate at the time of the first crevasse. How soon it would have thus operated is not known; the overseer naturally did not wait to find out.

In the case of these two crevasses these gates have paid for themselves many times over in reducing the damage that would otherwise have occurred. In addition, they preserved a line of communication, enabling the crevasse to be reached by water from the north, and thus effecting a material saving in assembling repair material at the locality.

This type of gate seems to possess many advantages for the upper gate of a lock that does not have too great draft, or for a safety gate above such a lock. In case of the ramming of the lower gate by a boat such an upper gate could promptly be raised in the torrential current that would result.

Another and different character of emergency gate was needed in the summit level of this canal.

Toward the eastern end of this summit the canal passes for a distance of 2 miles through a peat bog, locally known as Cecil's Slough.

This portion of the line had been difficult and expensive to excavate. It lies close to the divide between the Illinois and Mississippi rivers and was hard to drain.

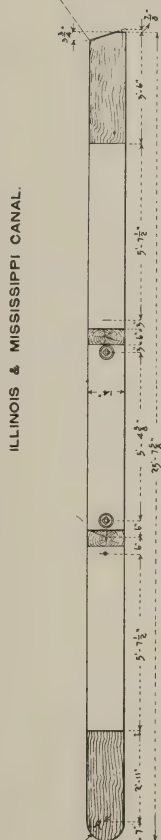
It was feared that after the canal was filled with water the sudden withdrawal of this water from this part of the canal, as would result from a crevasse in the feeder or summit, might cause the banks of the canal at Cecil's Slough to slough in, and thus involve great expense and delay in re-excavating.

The eastern end of the summit, except for a very short distance, is entirely in cut. For the short distance where it is in embankment the banks were very heavily reinforced. There is, therefore, scarcely any danger of a crevasse at this end of the summit level.

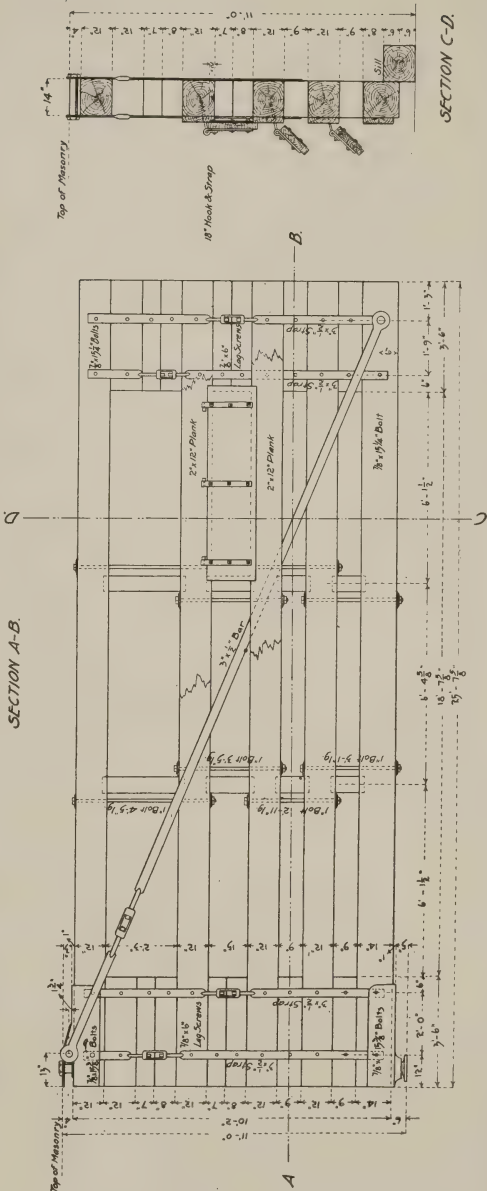
About a mile west of Cecil's Slough, where the canal passes from cut to embankment, the emergency gate, described below, was located. Here there was no difference in head of water available, and a different type of gate had to be used. At this point in the canal the ordinary flow of water in feeding the canal is in a gentle current from west to east. In case of a crevasse this flow would re-

CECIL'S SLOUGH EMERGENCY GATE

ILLINOIS & MISSISSIPPI CANAL.



SECTION A-B.



SECTION C-D.

Fig. 5. Cecil's Slough emergency gate, Illinois and Mississippi Canal.

Drawn by Fred W. Horvath, February, 1907.

Prepared under the direction of L. L. Wheeler, Assistant U.S. Engineer.

MAJOR CARPENT, CORPS OF ENGINEERS, U.S.A., IN CHARGE

PLATE IV.

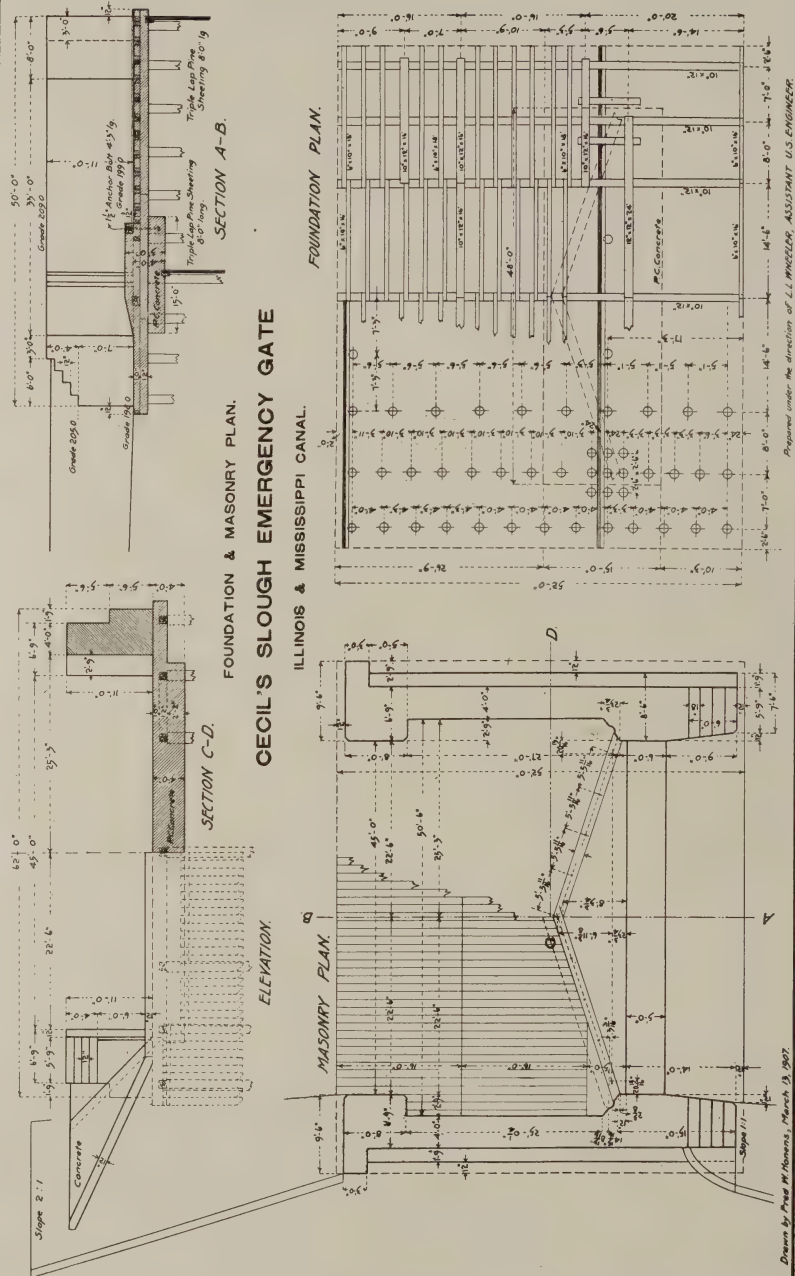


Fig. 6. Details of Cecil's Slough emergency gate.

verse, and would become a rapid rush of water from east to west. This westward rush, should it come, would have to be resisted, and meanwhile the gentle feeding flow eastward had to be provided for.

A movable dam of ordinary type that could be raised, piece by piece, in case of trouble would be too slow. The water would escape from the "slough" before such a dam could be raised, and the mischief would have been done.

The gate finally selected was suggested by Assistant Engineer

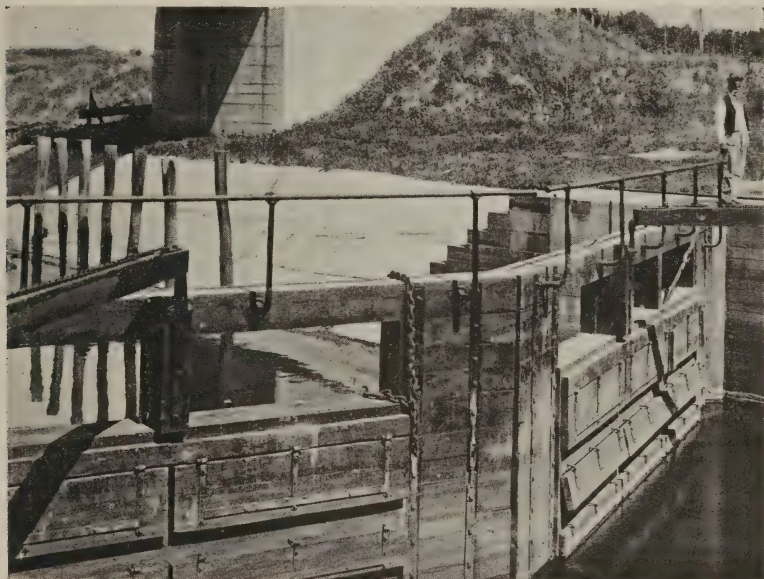


Fig. 7. Emergency gate at Cecil's Slough, looking against the usual current.

L. L. Wheeler and designed, under his immediate supervision, by Mr. Honens. This design can be seen in the drawings and photograph herewith.

This gate is of the ordinary mitering type of two leaves, each leaf built up of horizontal timbers, with the necessary spacing timbers between, all suitably tied together by metal straps, adzed to fit the hollow quoins and sawed to miter correctly.

This gate miters toward the east so as to resist water pressure coming from that direction. The spaces between its horizontal timbers are closed with hinged flaps, which are shut and held tight by water pressure from the eastward, but which swing open and

allow water to pass, as is normally the case, the flow of water feeding the canal is from the westward.

This gate is kept closed except when a boat has to be passed, and the two leaves are held together by a chain to prevent accidental opening. The gate is at once closed again when the boat has passed.

A reliable man has to be kept here at all times, and a house is provided for him to live in.

At the time of both crevasses, heretofore referred to, this gate successfully prevented any sudden outrush of water from the eastern end of the summit level. The water thus held there gradually passed out through the locks at the eastern end of the canal, but so slowly as to cause no sloughing of the banks in Cecil's Slough.

At the time of the second of these two crevasses there were several boats in the summit level, and they were all passed through this gate to the eastward before the current became too strong to permit operation of the gate.

CONCRETE CORE WALL IN MOLINE POOL DAM IN MISSISSIPPI RIVER AT MOLINE, ILL.

BY

J. B. BASSETT

*Member American Society of Civil Engineers
Assistant Engineer*

The PROFESSIONAL MEMOIRS of October-December, 1909, presented a very interesting article on under-water concrete in pier foundations at Oswego Harbor, N. Y., placed seventy years ago. Lieut. W. L. Guthrie's statement that the concrete is still sound is noted with considerable satisfaction by the writer, who is now engaged in building a concrete wall in practically the same manner at Moline, Ill., under the supervision of Maj. C. S. Riché, Corps of Engineers, U. S. Army.

A word as to the conditions which made it advisable to build this wall will help to a better understanding of what follows.

The Mississippi River at Moline is divided into two parts, known locally as the "Main Channel" and the "Moline Pool." The pool is formed and the two channels divided, by a longitudinal dam, the lower end of which is at Moline Lock. The lock lies on the channel side of Rock Island (called Arsenal Island), owned by the United States Government and occupied by the Rock Island Arsenal, the head of which island lies about opposite Twentieth street, in Moline. The arsenal water-power station, and also one of private ownership, lie between Arsenal Island and the Moline shore. The head for their power is obtained by the above-mentioned longitudinal dam, which extends upstream to a point just above what is known as Duck Creek Chain, in the main channel of the river, about 3 miles. The fall at low water in this 3 miles is about 8 feet.

The lower half mile of the dam is practically new, having been constructed in 1906 and 1907, at the time of the construction of the lock. This part is built of gravelly sand, heavily riprapped with rock obtained from the nearby channel excavations, to a height of 2 feet above any known high water. Above this half-mile stretch the dam is old, having been built in sections, the beginning of construction dating back to the sixties. About 2,300 feet at the lower

end of the old portion of the dam is built of rock-filled cribs reinforced on the outside with rock, some of which was laid by hand in the shape of paving. This portion, except at a few points, rises above high water, but leaks badly in spots. The remainder of the dam was constructed of sand-filled cofferdam, double-lap sheathing of mill slabs, etc., and all covered with loose rock. This portion was very irregular as to height and acted as a spillway during high water stages of the river. It was, therefore, subject to disintegration from the top, and crevasses of considerable size occurred annually, which heretofore had been repaired by the use of waste rock from the channel excavation. The expense of this repair work was inconsiderable, as the excavated material had to be wasted,

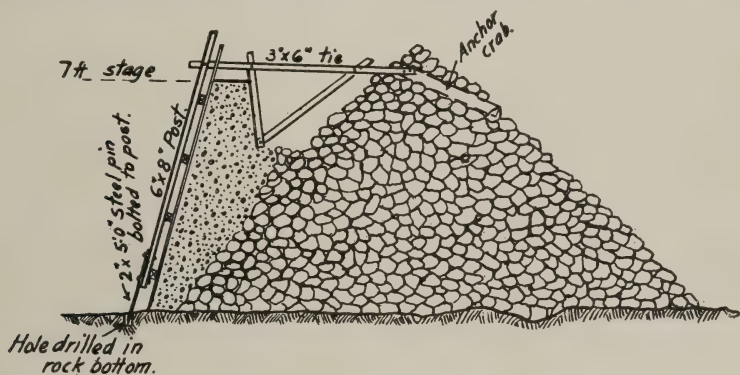


Old dam of waste rock from adjacent channel excavation.

anyway, and it cost no more to place it on the dam than to dispose of it in other ways. In anticipation of the time when the completion of the channel excavation would exhaust the supply of rock available for this purpose, it became necessary to adopt some method of making the dam permanently secure. In this day and age of concrete construction, that material was naturally turned to for a solution of the problem, and the writer was directed to make a report on the subject. After considerable study, it was decided that the best plan would be to build a concrete wall on the pool side of the dam to a uniform height, then pile rock, etc., against its face up to the crest, and make the wall become eventually a core wall in fact as well as in name. It will be noted that in this wall the crest is really the vital part, all the crevasses occurring from disintegration beginning at the top.

Following the above general plan, about 6,300 linear feet of wall

has been constructed during the past two seasons. In addition to the wall proper, the fill on the back, or river side is leveled down to a grade a few inches below the crest of the wall, and after being thoroughly washed and puddled with a stream of water under heavy pressure, is slushed over with a layer of wet concrete and smoothed up to the elevation of the wall. The average thickness of the paving above the level of the backfill is about 5 inches; but the effective depth is much more, owing to the wet concrete sinking into the voids of the rock. On the portion constructed in 1908 the paving averages 19 feet in width and slopes slightly toward the river side. After last spring's high-water season, it was found that the loose rock immediately under the lower edge of the paving had

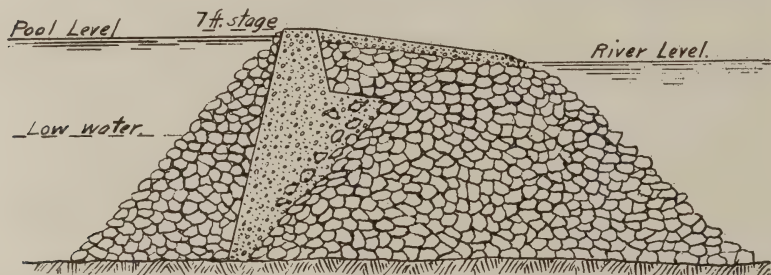


Detail of forming in place with concrete filling.

been washed away to some extent, although the concrete was not broken down except at one point where a small piece had fallen. Along the wall constructed in 1909 the paving is about 15 feet in width, due to the fact that there is much less material in this portion of the dam; but it is sloped toward the river side so that the outer edge will be under the surface of the water in the river at times of spill. In its original condition the dam was very irregular as to alignment, width and slope of sides. In constructing the wall the general line of the dam is followed, but the small irregularities are smoothed out.

The construction details are as follows: a dipper dredge is first employed to dig a trench along the toe of the dam to steepen the slope to its most abrupt angle of repose and to get down through the mud, sand, etc., to the solid rock bottom. Following the dredge a drillboat is employed to drill holes 10 feet apart along the toe of

the slope and approximately 3 feet therefrom. These holes are carefully placed, as the alignment of the wall depends on their proper location. Upright 6 by 8 inch form posts having a 2-inch steel rod, pointed on the lower end, bolted thereto, and allowed to extend about $1\frac{1}{2}$ feet below the end of the post, are then set, being dropped into the holes by the drillboat crew as fast as the holes are drilled, and left standing. Later the posts are lined up, slanted to a batter of about 1 to $3\frac{1}{2}$, and tied to anchorages in the rock dam by 3 by 6 inch strips bolted to the sides of the posts. The remainder of the form consists of horizontal 6 by 6 inch waling strips spaced by means of sink planks about $3\frac{1}{2}$ feet between centers, and 2-inch plank sheathing set on end to make as good a contact as possible with the irregular set rock bottom. It will be noted that only the face side of the wall is formed, the rough slope of the dam forming



Completed wall and apron with rock filling

the back side, except near the top, where the section is reduced to finish to a 2-foot width of coping.

The concrete plant was erected on a flat barge and consists of a rolling drum mixer and small, stiff-leg derrick with a 40-foot boom, together with the necessary boilers, hoisting apparatus, etc. This barge is floated alongside the form, with the gravel and cement barges on its other side. A straight sided, bottom-dumping bucket was designed for the work, arranged with two doors joining at the center and held shut by latches that can be tripped at will by latch strings. The concrete is deposited directly in the water with this bucket with very little agitation or loss of cement. For conveying the raw material to the mixer a special arrangement of an automatically dumping skip car was devised. A hinged and counter-weighted track extension allows the car to run out to the center of the gravel barge moored alongside, where it is filled by hand. The car itself is gaged so that the proper quantity may be

secured. A small barge containing the cement is moored alongside the gravel barge, the cement being carried a few steps by hand and dumped into the skip car from the containing sacks.

The proportions used average about 1 cement to 6 gravel. For the deeper portions of the wall, the gravel is reduced to about a 1-to-5 mixture to allow for some loss of cement, but the top of the dam is made of proportions of about 1 to 7. The gravel is furnished on United States barges by contract, being pumped direct from the river bed. It is not screened and re-mixed, as is the practice in some localities, since the natural mixture is quite uniform and tests show voids running from 12.5 to 17 per cent. The depth of water



New dam, showing concrete wall and apron.

in which concrete has been deposited varies from 5.5 to 17 feet. A considerable length of wall was built with the depth at the latter figure. In this case it was found inadvisable to attempt to carry the wall to completed height in one day, due to the excessive pressure on this style of form. It can be readily seen that a continuous contact between the form and the rough rock bottom would not be had. Occasionally, a stone would fall from the dam and, lodging along the line of the form, would prevent the sheathing from reaching to the proper depth, and a hole would be the result. It was found that concrete to a height of 3 or 4 feet would not run out, but if an attempt was made to carry the section to completion a leak would result, and, once started, it could not be stopped until equilibrium was restored. For this reason the custom was established

of building the deeper sections in two layers. Scrap steel rods, etc., in short lengths were stuck into the first layer to assist in bonding.

When the work was started, alternate sections were constructed, the intermediate sections being filled later; but in some cases where the dam behind the wall had quite a strong leakage it was found better to build continuously and push the leak ahead, each day's work being ended at a bulkhead. Later, this practice was followed altogether. Some cement was lost at points opposite the leaks, but not enough to materially weaken the dam. It must be remembered that the upper part of this wall is the vital part, as the dam breaks from disintegration on the crest. For this reason a reinforcing rod of about seven-eighths inch diameter is run longitudinally about 6 inches below the coping of the wall, tied by 8-foot rods set vertically near the face of the wall and bent at the top to hook over the longitudinal rod. This is done to hold in place any chunks of concrete which might come loose through shrinkage cracks or from impact of running ice.

The work is being conducted by hired labor, and the wages paid on the concrete outfit are as follows:

One foreman, at \$90 per month; 1 derrickman, at \$90 per month; 2 firemen, at \$40 per month; 1 hoistman on conveyor, at \$40 per month; 1 watchman, at \$40 per month; 11 laborers, at \$1 to \$1.25 per day, depending on scarcity of labor. Also, the drillboat crew, of 1 drillrunner, at \$60 per month, and 1 fireman, at \$40 per month.

Subsistence and sleeping quarters are furnished to all employees in addition to the above wages. Eight hours constitute a day's work, and the usual Saturday half-holidays are allowed at full pay during July, August, and September. Full pay is allowed to all employees for all legal holidays. Weather conditions are usually good in the summer season, but about six weeks in the spring and four weeks at the end of the season in November are usually attended by storms and exceedingly high winds.

The cement is taken from the cars and stored in a warehouse and afterwards loaded on the barges by hand. All cement is tested in a laboratory on the office boat.

The dredging and towing expense is also charged for the time put in by the dredge at digging the trench and by the towboat in carrying the various supplies to the work.

A cost statement of the work to date is as follows:

Cost Statement.

Expenditures, 1907		\$8,043.38
Expenditures, 1908 :		
Vouchers paid	\$22,307.34	
Quota R. I. office charges	680.85	
	<u>\$22,988.19</u>	
Less material, etc., on hand	3,792.37	
		<u>\$19,195.82</u>
Expenditures, 1909 :		
Vouchers paid	\$33,561.28	
On hand (1908 cost statement)	3,792.37	
Quota miscellaneous charges	375.12	
Quota R. I. office charges	1,380.07	
	<u>\$39,108.84</u>	
On hand December 31, 1909, cement	\$963.60	
Salvage on plant (60 per cent, \$3,959.98)	2,375.99	
	<u>\$3,339.59</u>	
		<u>\$35,769.25</u>
Miscellaneous		283.40
		<u>\$35,485.85</u>
Total net expenditures		<u>\$62,725.05</u>
13,112.6 cubic yards concrete, 6,301.8 linear feet of wall.		

Items.	Amount.	Cost per cubic yard of con- crete.	Cost per linear foot of wall.
Preliminary expense (plant equipment, warehouse etc.).	\$6,530.12	\$0.4980	\$1.037
Quota miscellaneous charges	375.12	.0286	
Superintendence and office :			
Field	5,551.26	\$0.4233	
Quota R. I. office charges	2,060.92	.1572	
Total		<u>\$0.5805</u>	
Excavation	1,241.56	.0947	
Forms :			
Material	2,752.39	\$0.2099	
Labor	2,514.95	.1917	
Drilling	660.67	.0504	
Drilling, coal for	186.53	.0142	
Total		<u>\$0.4662</u>	
Materials :			
Cement	17,952.72	\$1.3691	8.917
Cement handling	936.02	.0714	
Cement tests	627.39	.0479	
Gravel	7,140.71	.5446	
Reinforcement	290.08	.0221	
Towing	2,889.68	.2204	
Towing, coal for	942.03	.0718	
Total		<u>\$2.3473</u>	
Mixing and depositing :			
Labor	7,890.41	\$0.6017	
Coal	843.10	.0643	
Total		<u>\$0.6660</u>	
Backfilling	766.47	.0585	
Plant repairs	572.92	.0437	
Total	<u>\$62,725.05</u>	<u>\$4.7835</u>	<u>\$9.954</u>
Miscellaneous	283.40	.0216	.045
Plant charge (rental)	4,995.74	.3810	.792
Total, including plant charge	<u>\$68,004.19</u>	<u>\$5.1861</u>	<u>\$10.791</u>

The above statement includes all money spent on the work in plant construction and operation, material, and supplies of all kinds, repairs during season, superintendence, field and main office charges and a plant charge presumed to be equal to its rental charge were it not owned by the United States Government.

The strengthening of this dam is of great importance in the now approved 6-foot channel project, in that the low-water level in Moline Pool is to be raised 2 feet above present height of 4 feet minimum, and the dam will have to stand an added pressure due to this increase in height.

There is a total length of about one and one-third miles of the wall yet to be built.

GERMAN REGULATIONS FOR FIELD FORTIFICATIONS AND CONCLUSIONS REACHED IN RUSSIA FROM THE BATTLES IN DEFENSIVE POSITIONS IN MANCHURIA*

While the battles were still being waged in Manchuria, military students began to analyze them in their various aspects, seeking to secure information of value to the great armies of the world. The data, at first incomplete, inexact, and often incorrect, become more precise when the reports of competent persons permitted the events and their causes to be better understood. Thus, when the war was scarcely finished, its most important lessons were already formulated in the regulations of the great military powers, even before the two belligerents themselves had been able to profit by the experience gained.

A complete account of all the events of the war must be deferred for still some years, but fairly complete accounts of the different periods of which it is composed are already sufficiently numerous to permit one to weigh, more or less justly, the conclusions which the participants themselves and eyewitnesses have drawn therefrom. It is, moreover, of great interest to see how far this practical experience agrees with the theoretical conclusions resulting from a study of the facts, in order to see whether or not these conclusions are correct. With this in mind we should like to draw attention to a book by a Russian officer of engineers, S. A. Tchabel, entitled, *The Different Types of Field Works Constructed in the Russo-Japanese War*, with an atlas of thirty-five plates and numerous drawings. The author does not confine himself to a description of these works by word and drawing, but he also explains the reasons which led to these forms and the manner in which they were practically realized, and finally he indicates the results obtained and thus permits the reader to form his own judgment. S. A. Tchabel took part in the war; wherever he was not himself engaged in the

*Translation from *The Militär Wochenblatt* by the Editorial Staff, assisted by First Lieut. C. L. Hall, Corps of Engineers.

construction of these works (Liaoyang, Mukden, Guntchulin, etc.), he was, at any rate, thoroughly well acquainted with them.

The manner in which the author describes how these works were developed under local and personal conditions, and the conclusions which he draws as to the utility of these works, make his book an excellent subject for comparison with the German Regulations for Infantry Maneuvers and the Regulations for Field Fortifications of the German Army.

It is interesting, in the first place, to notice, according to the description of the author, how the existing conditions led to the construction of such extensive and strong field works; and how, in spite of that, these works did not give the results expected. The German regulations say (paragraph 5) that field fortifications "should permit the commander to economize his troops to secure strong reserves at the decisive point." The defensive imposed upon the Russians at first, by reason of their numerical inferiority, permitted the Japanese to choose the manner in which they should gain the tactical decision. Success by envelopment became more and more frequent, and later the success of the enemy weighed upon the Russians, even after their numbers equaled those of the Japanese and even exceeded them. It is possible that on the Russian side it was known to be desirable to employ strong reserves, held in rear, in an offensive manner in the course of the battle, although this idea was never realized. The tendency to keep strong reserves weakened in every case the force deployed on the defensive in front, the more as the turning movement of the Japanese led to a greater and greater extension of the Russian wings. Instead of supporting these wings by means of reserves the Russians bent them back and continued the work of field fortification, by creating strong defensive positions on the flanks. The more these defensive works were extended the more was the offensive force of the troops weakened and the tendency increased to make up for this weakness by increasing the strength of the defensive works.

Positions of refuge on the second line were not brought into use until after the defeat of the troops of the extended first line. We can not tell from the book to what extent the existence of these positions of refuge influenced the leaders not to take the offensive with the reserves; it may be that the leaders themselves were not conscious of such influence. But the weakening of the first line by having strong positions of refuge in rear proves that the movement

of troops is controlled by field fortifications, as the German regulations point out. On the other hand, the events and experience of the war have demonstrated that the passive force of these works did, in a measure, accomplish what was expected of them.

In spite of the great resisting power and the numerous successful passive defenses made of these positions of refuge; in spite of the great advantages which they offered when the troops retired before the victorious enemy and it was a question of organizing a retreat, the author arrives at the conclusion contained in paragraph 21 of the German regulations that "it may be taken as a guiding principle to have but one line, which should be strengthened by all possible means." This conclusion has not always been so clearly stated. The French regulations, for example, express a preference for advanced positions. It becomes all the more interesting to note that the author bases his opinion on practical experience, saying that the intensity and the duration of modern battles bring such a severe strain on the moral and physical strength of the troops that they can not be expected to bear the brunt of battle several times in succession.

This principle of a single fortified line is indicated in the German regulations, but for other reasons, such as a better view of the tactical movements, simpler control, and unity of action. We know from participants in the war that the Russian troops in many cases maintained themselves for many days in their advanced positions, always strongly entrenched, and that they finally effected an orderly retreat therefrom back to the principal position, and put up a successful resistance there against the Japanese attacks. The cases where this could not be done must have made a strong impression on the mind of the Russian author to make him declare, in principle, in favor of a single line of combat.

This would explain also why he rejects points of support in rear of the defensive line, which regularly formed a part of almost all of the Russian fortified lines. The German regulations also mention them, but with certain restrictions. Paragraph 25 says: "Behind threatened points, and behind those where the terrain is favorable, special points of support may be constructed."

They lay stress upon the two restrictions, the second of which (favorable terrain) is given great weight in Tchabel's book.

According to him, it has been established by experience that it is not practicable to construct trenches on the first line and points

of support on the second. The trenches were located in such a manner as to give the best field of fire, and it was necessary, in consequence, to be content with a poorer field of fire for the points of support. This is why the latter could not be made effective use of, as was hoped, at the moment when the trenches were abandoned. The trenches were held until the last moment, the struggle sometimes lasting several days, and the losses were considerable. The enemy advanced up to assaulting distance, and was not sufficiently held back by the redoubts. It resulted that at the moment when the trenches were abandoned to fall back on the points of support, the losses were increased and disorder followed. With the resulting loss of morale it was not possible for the troops to establish themselves in the points of support. This is why these latter were pushed farther and farther to the front, even up to the lines of trenches themselves.

Thus was given up one advantage which it was hoped to obtain with the points of support in rear. It was thought that the trenches would mask the points of support and prevent them from being the object of a well-regulated and effective fire. One thinks involuntarily of Plevna. The Russian artillery fired on the trenches of the Turks, established on the summit of the heights, but the redoubts which were located on the reverse slopes remained unnoticed, and repelled all attempts at assault. Did the Russians think they were profiting by this lesson? If such is the case, they made the error of not taking into account all the other conditions of the combat, and that is why their calculations were in error; they could not develop the full strength of the points of support at the decisive moment. Efficacy of fire became more important than cover. By advancing their points of support they gave up the idea of cover, but secured a valuable placing of the redoubts for the defense of the first line and a real re-enforcement of it. The terrible losses which the Russians suffered every time they quitted the trenches just before the decisive moment leads the author to say that one should not avoid the issue, but, on the contrary, meet it by maintaining himself in position and keeping up an effective fire.

The difficulty of capturing the redoubts, which it was almost impossible to attack in the daytime, led the Japanese to make more and more frequent use of night operations. The impossibility of repelling these attacks by fire led the Russians to construct extensive obstacles. They spread hundreds of thousands of square meters

of them around the great positions. Believing obstacles to be a remedy for all ills, they made immense zones of them around their fortifications, soon giving up all idea of the offensive. Thus they forced the Japanese to adopt the enveloping movement which paragraph 13 of the German regulations indicates as the probable result of these works. On the other hand, they were obliged to remain in place behind their own obstacles, and were not able to hold enough of the Japanese in their front so that they would not have sufficient force to execute the enveloping movement.

With obstacles of such dimensions it is evidently necessary to sacrifice in some degree the essential conditions which defensive works should fulfil, viz, effective field of fire for the defenders, and shelter against the enemy's fire. It was thought at first that artillery could not cause any considerable damage to obstacles, particularly to the wire entanglement. But the Russians soon recognized that they were mistaken in this respect. The obstacles suffered so much from artillery fire that Tehabel considers it the most effective means of destroying them. Perhaps the Germans do not fully appreciate the effectiveness of artillery fire against obstacles and do not give sufficient attention to providing cover therefor. The author decides that obstacles may be destroyed by artillery fire, and that they should therefore be well covered or concealed; he says that they should not be of such dimensions as to interfere with offensive action.

The Russians recognized that a defensive position should be easy to watch, that one should be able to move troops conveniently upon it, and that the communications in rear of the position should be improved. (Paragraph 17 of the German regulations.) They gave great weight to these considerations. The roads, bridges, and fords behind these positions could be counted by the hundreds. This is explained by the undeveloped condition of the country and the great number of troops. In spite of all these, the accounts of eye-witnesses indicate that all these means of communication were not sufficient to permit an orderly retreat in all cases, and disaster could not have been avoided if the Japanese had followed up the pursuit. It is to be expected that a commander thrown on the defensive will use every means at his disposal to strengthen the fighting position proper, but it is very dangerous on that account to neglect the means of communication in rear of the position; and these include not only the necessary roads and bridges, but also the

telegraph, the telephone, visual signals, wireless telegraph, and field railroads. The state of development of all these installations in the civilized nations of Europe tends to prevent our forming a just estimate of their value.

As a result of the peculiar circumstances in Manchuria and especially owing to the persistent tendency on the part of the Russians to remain on the defensive in strongly fortified positions, two important rules of the German regulations played no part in the Far East. Paragraph 23 says that the time available determines the kind of works to be built, and paragraph 34 that the works should, as a rule, be built by those who are to defend them. Time did not enter into consideration in the great works of the Russians. The great battles were separated by intervals of considerable time, which permitted them to make the positions as strong as they chose, and the configuration of the theater of war so circumscribed all the movements that they could foresee several months in advance where the next battle would take place, and fortify the position at will, making use of the inhabitants of the country.

In the beginning the Russians thought to content themselves with the simplest works (for example, kneeling trenches), although there was plenty of time, but soon they learned to their sorrow that the best was none too good. This experience once gained, thereafter they neglected nothing to make their positions as strong as possible.

The works were executed a long time before the troops that were to defend them were on the ground. Civilian labor, therefore, was used for the most part, and as a result they could not keep secret the disposition of their works; and, moreover, this method has the disadvantage that the troops who are to defend the works do not know them. The conditions resembled those that obtain in the case of a fortress which is put in a state of defense on the outbreak of war, the garrison that is to defend it arriving later. In both cases the troops have to defend works constructed by others. It is necessary that the troops become acquainted as quickly and as thoroughly as possible with the field of fire and the works to which they are assigned. In the case of a garrison there is generally time for this, but in the field the necessary time is usually lacking.

In some cases the Russian troops were assigned quite early to the sectors which they were to defend, and could therefore get their bearings, but often they only arrived in them at the last moment. This was particularly the case when the troops, having defended

advanced positions, fell back on the main line of defense or were driven from the latter farther to the rear, that is to say, when the enemy dictated the movement and the time.

These difficulties became so serious that finally General Linevitch was obliged to prescribe categorically the form and disposition of the groups of fortifications. Thus the principle of adapting them completely to the terrain was violated, but at least the troops took possession of works in which they could quickly orient themselves, the distribution of the companies was facilitated, and the direction of the battle simplified. Nevertheless, the course taken by the commander-in-chief caused some difficulty. Tchabel sees no good in it and asserts that the troops never could get used to it.

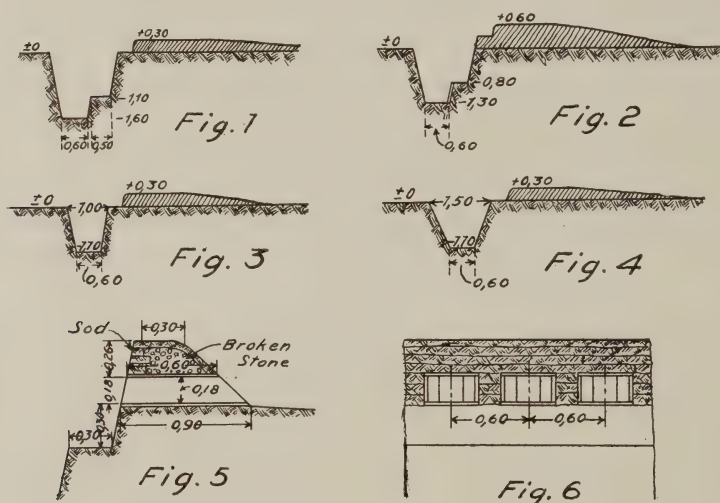
A good field of fire was considered of first importance by the Russians in the location and execution of their works. The cultivation of the country restricted in a great measure the view and the field of fire. The fields of kaoliang necessitated wide clearings in order to obtain a clear field of fire. The Russian author believes that sometimes they carried these clearings too far, forgetting that they would thereby disclose their positions to the enemy. All trees found within range were cut down to make shelter, although there were not many of them on the plains of Manchuria. They thus obtained a free view of the ground in front of their positions, but the Japanese artillery also profited by these clearings, which facilitated their fire against the Russian works. Tchabel himself thinks that the Japanese acted more prudently; they left the trees standing in front of their positions, which prevented observation and obliged the Russians to content themselves with a dispersed fire. This act of the Russians in cutting down all the trees soon forced them to have recourse to artificial screens to replace the trees.

Paragraph 45 of the German regulations says that only the lack of time can justify the construction of kneeling trenches, and that, as a general rule (paragraph 40), standing trenches should be provided. Practical experience forced the Russians to the same view, as has been stated above. Several different kinds of trenches were developed, but all were for standing riflemen, the depth from the crest of the parapet to the bottom of the trench being 2 meters. The German regulations indicate 1.90 meters. (Figs. 1 and 2.)

Paragraph 40 of the German regulations says that it is necessary to make a narrow, deep trench with steep slopes in order to diminish the effectiveness of artillery fire. Figure 3 shows a trench with

steep slopes cut in firm soil, and Fig. 4 one with slopes less steep in a medium soil. In Manchuria the steepest possible slopes were found necessary. As the clay soil, very solid in dry weather, could not resist the rain, steep slopes were secured by means of revetments. The trenches were given a width at the bottom of .75 meters (according to the German regulations .60 meters) and the banquette of .45 meters (.50 meters in the German regulations). Thus the trench afforded complete protection against infantry fire and also against shrapnel fire if the men were sitting on the banquette. It should be remarked, however, that neither of the adversaries had light field howitzers firing shrapnel.

While the German regulations indicate .30 meters as the normal



height of the parapet above the ground, it was necessary in Manchuria to raise this to .60 meter in order to be able to fire over the fields of kaoliang, the height of which is about .30 meters. The parapet was not made higher from considerations of concealment. For the same reason it was given a very gentle slope toward the front of 1 on 10 or, at most, 1 on 5, after the manner of a glacis. Experience indicates that the effects of light and shade on surfaces inclined at different angles, such as the natural surface of the ground and the artificial slope of the parapet, may render useless all attempts at concealment. To avoid disclosing their position to the enemy, the Russians finally adopted the practice of throwing to the rear the earth which was obtained from deepening the trenches

in such a manner that it did not show above the crest of the parapet.

The German regulations require (paragraph 40) that the location of the trenches and the line of fire should be such as to permit the ground in front to be covered. It is the configuration of the ground and its vegetation which determine whether it is preferable to raise the line of fire or to sink it to the level of the ground. It became the practice in Manchuria to make the trenches entirely in excavation without parapet, but this practice was found to be faulty. In addition to the fact that it involved considerably more work and gave a more restricted field of view and of fire, it was difficult to dispose of the earth taken from the trench. Scattering the earth in front of and behind the trench rendered its location more visible to the enemy than a parapet of medium height. The latter shows only a single line barely perceptible, while the earth spread out under the other plan forms a wide band, which, under the influence of the air and light, changes color in a few hours and is visible at a great distance. According to Tchabel, they soon gave up the trench constructed entirely in excavation, only making use of it on a crest where the excavated earth could be thrown on the reverse slope.

However, such a position for trenches is rarely possible; and they soon recognized that a trench entirely in excavation was less advantageous than one with a slight parapet. On the other hand, a trench on a slope toward the enemy is less advantageously located than one on the summit, because it is better illuminated, and so more readily seen from a distance. It was found that on slopes the lights and shades, visible from a distance, made the trench constructed entirely in excavation quite as visible as one with a parapet.

The campaign did not furnish conclusive information as to the advantage or disadvantage of loopholes in trenches. In speaking of loopholes in connection with fortress warfare (paragraphs 44, 131, and 132), the German regulations imply that they are of no great value in field works. It is recognized that loopholes really offer no more shelter than a straight firing crest, but they have, nevertheless, a certain influence on the morale of the troops. Such head-cover prevents the enemy from seeing the men's heads directly, and officers and men imagine instinctively that the enemy has less chance of hitting them. Troops take more kindly to trenches provided with loopholes, are less nervous in them, and fire better, be-

lieving that they are safer therein. It was customary in Manchuria to allow the troops to make loopholes or not, as they chose. Loopholes require considerable precautions to conceal them from the enemy, as the parapet provided with them is much more visible.

The German regulations are, therefore, quite right in declaring against them for field fortifications. In fortress warfare, on the other hand, their use is extensively provided for, and the extra work which they entail, even though considerable, is considered necessary. (Figs. 5 and 6.) The reason is that in fortress warfare the ranges become so short that it is no longer possible to conceal the works from the enemy; and, during the advanced stages of the siege, protection against infantry fire becomes the controlling consideration. However this may be, it must be admitted that loopholes do not afford complete protection against infantry fire and are difficult to conceal from the enemy.

The interior arrangements of the Russian trenches conformed in general to the German regulations. It has been already noted that it was found necessary torevet the slopes on account of the weather; this was regularly done. The necessary materials, brush, and planks, etc., were found in abundance in the villages; kaoliang was also much used. It is remarkable that the elbow rest, which the German regulations consider a normal feature, did not impress itself upon the Russian officers. It is, nevertheless, indispensable. When the officers did not require it to be made, perhaps for fear of diminishing the cover, the soldiers fixed a wooden shelf in the front slope of the trench, which served not only as an elbow rest, but also as a foothold to get out of the trench to deliver a bayonet attack on the Japanese.

Traverses were constructed at the same time as the trenches, of the form prescribed in the German regulations to be built after the trenches are completed. General use was made of these traverses, which were made quite narrow, since they had to be revetted, anyway, and every available foot of parapet was required to increase the intensity of fire. Their form is like that prescribed in the German regulations; the height in front being the same as that of the crest, sloping gently to the rear, the length corresponding to the width of the trench; they were .60 meters thick at the top (.50 meters in the German regulations) and from .90 to 1.20 meters thick at the bottom (1.00 meter), and they gave cover against infantry fire and fragments of shell and shrapnel. According to the

German regulations they should be spaced at intervals of 8 meters; in Manchuria this distance varied from 8 to 12 meters, which resulted not from considerations of the effect of the enemy's fire, but from considerations of discipline. The individual instruction of the soldiers was so defective and their independent action in battle so uncertain that it was necessary to maintain a severe fire discipline and a constant supervision over them. As traverses interfere with such control, the Russians reduced their number below what it should be from the other consideration; they even went so far as to omit them altogether in trenches exposed only to a frontal fire. But this course had its disadvantages, for the effectiveness of the Japanese shell fire was such that the advantage gained in discipline was more than offset by the increased losses, the greater nervousness of the men, and their resulting poorer marksmanship. Traverses, moreover, have still another advantage; they prevent the men from seeing the disastrous effects of the enemy's fire on each side of them.

The German regulations say nothing as to the capacity of shelters to be provided in relation to the total number of men occupying the trenches. Experience in Manchuria led to the practice of constructing them for *all* the troops. In the beginning of the campaign they built splinter-proof cover in the trenches for the observation stations only, providing shelters in special cover-trenches in rear of the fire trenches, connected with the latter by communicating trenches. The necessity of being able to quickly man the fire trenches, which is mentioned in the German regulations (paragraph 50), soon led the Russians to provide shelter in the trenches themselves. This was limited to splinter-proof cover, bomb-proofs being provided in rear. Against the Japanese shrapnel and common shell, a thickness of .20 meter of earth covered with kaoliang stalks and supported on stakes driven into the front slope of the trench was entirely sufficient. To obtain more complete overhead cover, this was extended to the rear so as to cover the whole trench, loopholes being made in the parapet. But this increased the height of the work, which, with the loopholes, made it too easily seen by the enemy. Such trenches were particularly difficult to conceal from view.

The trenches provided with all-over splinter-proof cover afforded sufficient cover against the distant fire of the enemy, but at short range open trenches were preferred. On this account they fre-

quently used a type of trench like that prescribed in the German regulations, with notched embrasures in the parapet. (Fig. 7.)

The light splinter-proof cover provided was sufficient, because the Japanese had no heavy field howitzers, and a less thickness of cover than one would have supposed proved sufficient against the bursting shells.

To render them completely safe against the enemy's fire, the Russians finally covered their shelters with beams .25 meters thick, on which was laid 1 meter of earth. So much material was necessary for such shelters that, even in the works prepared in advance, they were only constructed for a part of the troops.

To reduce to a minimum the number of direct hits on the shelters, the Russians used all of the means mentioned in paragraph 50 of the German regulations, *i. e.*, by placing them under the parapet to prevent their being seen from the front, by keeping their number and dimensions down to a minimum, and by distributing them over the whole front of the works.

Emplacements for machine guns were very different from those provided for them in paragraph 55 of the German regulations, shown in Figs. 8 and 9, because the Russian machine guns had quite a different carriage from the German and were provided with a shield. This shield, which could not be removed from the carriage, rendered them very difficult to conceal, and it is for this reason that the machine guns did not play the double rôle they should have played in the defense of points of support and in the flanking of the intervals, where, according to Tchabel, they would have been very useful. A machine gun which can be easily concealed and taken off its carriage is much more appropriate to this rôle than the wheeled machine guns of the Russians.

Covered ways and communicating trenches were made large use of in Manchuria. As the enemy kept up a constant fire on the ground in rear of the trenches, this was compulsory whenever the configuration of the ground and the vegetation permitted observation. In order not to increase the amount of earth work, they sought to utilize as much as possible the natural cover offered by the terrain; they did not arrive at this, it is true, until terrible losses had been sustained by not taking sufficient account of this principle. In order to procure the materials necessary for the retrenchments of the trenches, the shelters, etc., the Russians cut down, as has previously been mentioned, everything in the nature of a

tree, both in front of and behind the position. They thus deprived themselves, by their own fault, of an excellent mask, and had to replace them later by artificial works (communicating trenches). This is why the length of the communicating trenches was often considerable. In form they were like Fig. 10, from the German regulations; their useful height was 1.80 meters, minimum; more often 2.10 meters, so that they gave protection against infantry fire to a man standing and against shrapnel fire to a man crouching.

It is important for us to take account of the advantage that there is in preserving the natural vegetation in front of and behind the

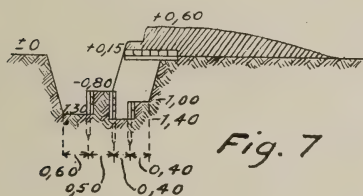


Fig. 7

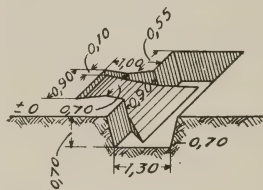


Fig. 8

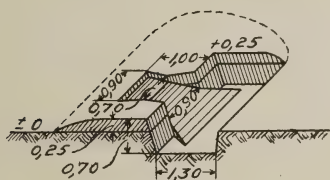


Fig. 9

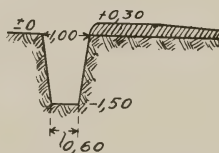


Fig. 10

trenches, and so economize on earthwork, for troops have a natural tendency to take the materials they need from the nearest possible source.

The communicating trenches leading to the firing trenches situated on slopes toward the enemy were evidently the most easily seen from a distance and the most exposed. But this condition will frequently occur. The German regulations say in paragraph 27 that it results in the following cases: when the firing line would otherwise be thrown in relief on the horizon and can not be concealed by a screen in rear, and when it is necessary to obtain a better field of fire at a sufficient distance from the friendly artillery. This last reason especially gives rise to long communicating trenches on the slope toward the enemy. It was found by experi-

ence that even when the greatest possible care was observed in laying out these communicating trenches, they stood out on the terrain in a black line, visible from a great distance, and gave the enemy's artillery the means of discovering the position. When they could not otherwise mask these trenches, the Russians covered them completely with branches or kaoliang stalks. This covering admitted sufficient light so that one could see to traverse them, but sometimes the color of the ground was different from that of the covering material used, so that it was necessary to cover it with a thin layer of earth, leaving openings here and there to admit light. The German regulations do not mention the subject of the visibility of communicating trenches on slopes toward the enemy. The experience of the Russians seems worthy of note.

They generally used a smaller bottom width for such trenches than the German regulations prescribe, .45 instead of .60 meters.

But this restriction has its disadvantages. It was difficult to pass in the trenches, special passing points being necessary; the movement of the wounded to the rear was complicated and even impracticable on litters, and finally it was impossible to move the Russian machine guns to the front through these trenches.

When the terrain did not render artificial cover unnecessary, they, as a rule, provided each fighting position with communicating trench leading to the rear, bringing these trenches together at a certain distance from the front. In this manner the different positions were connected with each other in such a way that if the enemy should capture a part of the line he could not extend immediately over the whole front of the position.

For the same reason the communicating trenches never led directly to a point of support, but passed to one side of the wire entanglements surrounding it. After some unfortunate experiences, they even avoided, in the case of advanced points of support, putting the lateral trenches in direct communication with the ditches in front of the redoubts by a passage through the wire entanglements.

Communicating trenches were given a zig-zag trace (paragraph 116 of the German regulations) to protect them from the fire of the enemy. But the necessity for rendering them impracticable for the enemy soon led to a departure from this practice, especially behind points of support. The last section of the communicating trench was laid out perpendicular to the position, in such a manner that it could be well enfiladed.

The great number of communicating trenches formed a serious obstacle to communication behind the fighting front. The troops were expected to confine themselves to the trenches, but for certain persons, officers, orderlies, etc., more direct routes are necessary, sacrificing cover. It was necessary to provide foot bridges or to make steps in the side slopes of the ditches. The minor details of these fortified positions conform naturally to those mentioned in the German regulations. Drains were constructed to dispose of rain water, although this often entailed a vast amount of work; ditches and sumps would have been quite sufficient. The water which falls directly in the trenches is small compared with that which runs into them from the surrounding ground. Therefore, the Russian engineers used every means to divert the surface water before it reached the trenches.

Wells were seldom dug in the trenches. Latrines were provided in rear of the trenches, as explained in paragraph 62 of the German regulations. They were always provided with cover and connected with the trenches by covered ways. The troops soon recognized the necessity for this work and performed it willingly, which proves how readily the soldier performs work that he realizes is necessary, no matter how disagreeable it may be.

The German regulations limit the use of works closed on all sides to a few cases when they offer particular advantages on favorable ground, such as to support a threatened point or when a special point is to be occupied by a few troops or is subject to attack by surprise and without artillery. In the ordinary case a point of support composed of a group of works is preferable. (Paragraph 24 of the regulations.) This is why the German regulations have so little to say about points of support. (Paragraphs 63 to 65.) They are made up simply of a group of trenches giving fire in all directions and surrounded, if necessary, by an exterior ditch. Beyond this there is nothing peculiar about them. We can scarcely compare the redoubts of the Russians with the works described in the German regulations, but as these closed points of support played a great part in all the Russian positions, and as they seem likely to retain their importance in the future, it will be interesting to say a few more words on their arrangement and their use.

The Russians always used closed works for the points of support. Only such works, in their opinion, would serve the purpose. If the position was not abandoned before the final assault, hand-to-hand fighting generally resulted. In fact, supporting points consisting

of works open to the rear have little more resisting power than ordinary trenches. At most, they offer a few more difficulties to the final assault, but they do not have a superior power of resistance against an adversary, who, having pierced the line at another point, directs his attacks against the flanks and rear of the adjacent line. Closed supporting points surrounded by obstacles and arranged to permit fire in all directions are the only safe ones against such an attack.

The Russians realized perfectly that closed supporting points were less suitable for the first line than trenches, because they can not be so well adapted to the terrain. But for other reasons, which have been mentioned above, they were led to advance their supporting points from the second to the first line. These points of support consisted generally of a trench and a ditch, as is provided in the German regulations, and in the ditch were placed obstacles concealed from the enemy. From this arrangement a feature was developed which is characteristic of this war. The marksmanship of the Russians became poorer as the Japanese approached the obstacles in the ditch, that is to say, at from 10 to 12 meters from the firing crest. Moreover, the adoption of hand grenades made it necessary to advance the obstacles so that a man could not throw them from the far side of the obstacle into the redoubt. A second line of obstacles was therefore provided at about 50 meters from the firing crest. The outer obstacle was considered of more value than the other; it was begun first, and to it was attributed later the principal force of resistance of the whole work.

It was expected that the enemy would try to gain a lodgment in the ditch from whence to throw hand grenades into the work. This danger was particularly great where the ditch, having steep slopes, was dug close against the parapet. They tried to provide for enfilading these ditches without arriving at a satisfactory result. This is why they soon came to adopt a parapet gently sloping toward the front and a ditch whose interior slope was of the same slight inclination, so that the obstacles in the ditch could be covered by fire from the parapet. Moreover, steps were taken to facilitate night firing. The slope of the parapet was made so that the fire of a rifle laid upon it would just graze the ground in front.

The profile of the redoubt was ordinarily established so that the rifleman stood on the natural surface of the ground. Sometimes the line of fire was raised and a banquette provided. In order not to be too visible from the front, the work should be raised very

little above the natural surface of the ground. It was soon recognized that this was of importance, and for the same reason they generally gave up open embrasures, or loopholes, although it is quite certain that they made the troops feel more secure. For the same reason they provided overhead cover for observation posts only and to cover the entrance to the works. To render the redoubts as invisible as possible, they avoided all acute angles in the trace and removed the piles of excavated earth.

The interior slopes of the parapet and of the ditch, which were ordinarily provided with a revetment, presented a similar appearance to the fire trenches. As it was impossible to avoid enfilade fire on some parts of the line, it was necessary to reinforce the trenches with traverses (up to 2.10 meters in thickness), which provided cover against field gun shells. In order not to reduce the firing parapet, it was given an offset and passed in front of the traverse.

As a rule, shelters were provided for all of the troops. In practice it was found disadvantageous to have them grouped close together. They were made individually small and distributed over the entire work. If time permitted, they made shelters affording complete cover from the fire of the enemy for one-fourth or one-third of the troops, in addition to the bomb-proofs in the interior of the redoubt. Moreover, special shelters were constructed for the officers and for dressing stations and telephones. The latrines were placed ordinarily outside of the redoubts, on the road leading to the rear. If possible, each redoubt was provided with a well.

Covered trenches served as communications within the works. They were shallower than the exterior trenches, so that the rain water would not flood out the interior of the works.

The size of the supporting points was considerable, being intended for from one to four companies (200 to 800 men). Under actual test these large redoubts did not give the best results, because their firing front was small compared to the number of troops that they contained. This is why it was decided later to form battalion groups, by putting a one-company trench on each flank of the supporting point, itself containing two companies. These trenches were placed so that they could be enfiladed from the flank faces of the redoubt, which was the more necessary, because they had ordinarily no obstacles in front of them.

The troops in the trenches and those in the supporting point belonged to the same unit, so that for purposes of command they formed a single group. The lateral trenches were connected with

the ditch of the supporting point, and from these communicating trenches led to the interior of the work. Even by barring these connections with obstacles, the use of them was not entirely denied to an enemy who should capture one or both of the adjacent trenches. It will be understood, therefore, that it came to be considered preferable to make the lateral trenches independent of the supporting points, providing shelters for their troops in special trenches behind the line and connecting these with the supporting points.

One is somewhat surprised to hear Tchabel say that there is no need of obstacles in front of these trenches, because they will be abandoned before the final assault, the troops in them falling back to the supporting point. By such procedure the enemy is permitted to pierce the line and envelop the supporting point. It is more in accord with the German regulations to hold the trenches to the last, by increasing the volume of fire as much as possible, and this course has much better chance of success if the enemy is delayed by obstacles within effective range.

The Russian supporting points on the first line were, in many cases, very effective. They assisted in repelling the attack of the Japanese even when it was directed against the weaker lines in the intervals. Thanks to them, the Japanese reinforcements were many times held back until the counter-attack of the Russian reserves could be developed; and finally they covered the retreat of the Russian troops when it became necessary to abandon the trenches in the intervals.

They considered that a similar rôle devolved upon the supporting points in rear of the first line. These ought also to serve as a base for the counterattack of the reserves. It is not unlikely that they were often useful in this way. Nevertheless, the Russian author arrives at the conclusion that if the troops in them had been on the first line, it would not have been pierced at all. This corresponds to the German view of the matter.

Considering the dimensions originally given to the supporting points, it is not surprising that they should have been provided with keeps, although the war did not offer an opportunity to use them. Tchabel believes that if the enemy has succeeded in penetrating into the work the keep has no chance of changing the course of events.

Strongly built supporting points can occasionally offer considerable passive resistance, but, in contrast with trenches which are

easily concealed, they offer such a good target to the curved fire of modern artillery that their value is very problematical.

As to villages and farm houses, a use was made of them in Manchuria, quite beyond what was expected. It was thought that their resisting power against modern artillery would be so slight that but little use could be expected of them as supporting points. It was soon discovered, however, that the increased effectiveness of modern projectiles against live targets had been secured by a sacrifice of their effect on material objects. The Japanese Shimose shell exploded on the slightest impact, even against the light walls of the Manchurian villages. The losses caused by such shots were quite local, and the surrounding walls stopped the fragments effectively. Small buildings, even sheds, offered excellent shelter for soldiers. As all the Manchurian villages are surrounded by high walls as a protection against wandering brigands, the Russians soon learned to transform them into very serviceable supporting points; it was only necessary to make loopholes in the walls, to cut steps for mounting the ramparts, and place obstacles in their front. When the firing front so formed was not sufficiently extended, they dug trenches on each flank, as was done with the redoubts.

The incendiary effect of modern projectiles was found to be very slight.

Central positions (keeps) were built, as provided in paragraph 74 of the German regulations, by making use of the buildings found in the center of the villages. If no suitable buildings could be found there, a strong redoubt was built in rear of the village. The field of fire around such a keep should be at least 40 meters.

In considering the lessons which the Manchurian war can teach us, it must be remembered that neither of the adversaries had field artillery giving an effective curved fire, while the European armies are generally well provided with such weapons.

In the construction of obstacles it is generally necessary to limit oneself to the materials to be found in the theater of war. These works will therefore always have some variety. The principal obstacles in Manchuria were the wire entanglement, military pits (*trous de loup*), abatis, and mines. These obstacles will all have a place in a European war, but it is quite impossible that they should have such an extensive use. The rapid movements that will characterize a European war will not permit such extensive works to be completed, and, moreover, we can not count on such a completely passive attitude on the part of the enemy.

We have already spoken of the two entanglements, close and

advanced, which were placed in front of the supporting points. The upright abatis, in the ditch, such as is provided for in the German regulations, was not used in the Far East. We have already indicated that artillery fire proved most effective against obstacles. As the German regulations remark, it will rarely be possible to provide cover for the obstacles and as a result no very great usefulness can be expected of them. If cover is lacking, they should at least be masked, as the German regulations provide. The value of obstacles is not measured by their extent; they can only fulfil their rôle when they are covered by an effective fire.

While the German regulations give the wire entanglement as the best obstacle, Tchabel considers military pits the most effective. The new German regulations do not even mention them. The military pits described by Tchabel require a great amount of work; their diameter at the top is 1.80 meters; at the bottom .90 meters; their depth is 1.80 meters and they should be arranged in three or five rows, with their edges, at most, .50 meters apart. The excavated earth serves to form a covering glacis. These figures indicate that military pits can only be constructed in firm soil.

The dimensions of the wire entanglements constructed in Manchuria differ somewhat from the examples given in the German regulations. The Russians drove the stakes in seven rows, 1 meter between rows, and 2 meters laterally between stakes; the height of the stakes above the ground varying from .80 to 1.20 meters. The German regulations speak only of stakes of 1.50 to 2 meters, the height above the ground being variable. It is pointed out that high stakes can be neither covered nor masked, while low stakes are not very difficult to get through. Instead of wooden posts, iron ones were sometimes used to an advantage. For the entanglement smooth or barb wire was used; if it necessary to economize on barb wire, it was used on the rows toward the enemy, smooth wire being used for the rest. If time permitted, a wire entanglement was built over the military pits. Tchabel claims that this is very effective.

Abatis of branches and trees were laid down as provided in the German regulations, but no great use could be made of them because the country was poor in trees and did not furnish the necessary materials.

As to land mines, the Russian engineers, in accord with the German regulations on field works and their regulations on the use of explosives, attribute to them mainly a moral effect. The German regulations prescribe particularly the common mine; according to Tchabel, the Russians used with equal success the fougasse. Com-

mon mines were laid ordinarily in several rows, the depth of the charge below the ground being from 1.50 to 2 meters, the weight of the charge being 16 kg. of powder; the charge of a fougasse was somewhat greater (24 kg.). Opinion is divided as to the effectiveness of these obstacles. The German regulations say that with automatic mines superintendence may be dispensed with, and that it is sufficient to indicate practicable passages through them for friendly troops. The Russian author, on the other hand, claims that mines of this kind were often fatal to friendly troops, that they call for numerous observation posts, and that electric mines required a great deal of care and had to be controlled at every point. The best distance for mines seems to be from 40 to 50 meters in front of the position. A shorter distance exposed the works to attack by hand grenades and to the fire of artillery directed against the belt of mines, a greater distance rendered their supervision more difficult and made it easier for the enemy to destroy them.

In the beginning, great importance was not attached to natural or artificial cover for artillery pieces, although they were not provided with shields, but the losses incurred soon led them to attach great importance to cover, at least up to the moment of the assault. The time available permitted the construction of carefully prepared emplacements for artillery. No particular type for such works was developed; each unit of troops adopted a special form, appropriate to its needs. Experience showed here how correct the regulation is that requires the troops that are to defend a position to fortify it themselves. When other troops or civilian laborers constructed the works intended for the artillery, they were never satisfactory; it resulted that later, if the troops themselves could not execute the work, at least an artillery officer was consulted as to their design.

The artillery fully recognized the value of cover, and the men applied themselves with great diligence, even during battle, to the work of obtaining it. According to the German regulations, the artillery is used, even in fortified field positions, in batteries with an interval of from 10 to 20 yards between pieces. The Russians rarely used compact batteries, but placed the pieces singly or in groups, in widely separated emplacements. At first the pieces were placed on the natural ground and the earth necessary for the parapet was taken from the trenches dug on each side for the gunners. Later the guns were placed in pits and were even given splinter-proof cover, which is not recognized in the German regula-

tions. Little by little they came to adopt a complete cover with an embrasure in front, which was closed as much as possible with sand bags as soon as the direction of the enemy was determined. For guns provided with recoil cylinders and shields, such complete shelter is no longer necessary, although the German regulations recommend that they always be placed behind cover. If they wished to advance the caissons to the battery, in order to facilitate the supply of ammunition, the Russians dug pits for them, partially or entirely covered; these pits were not alongside of the piece, as the German regulations prescribe (Fig. 11), but were between two gun pits. Communicating trenches between adjacent gun pits

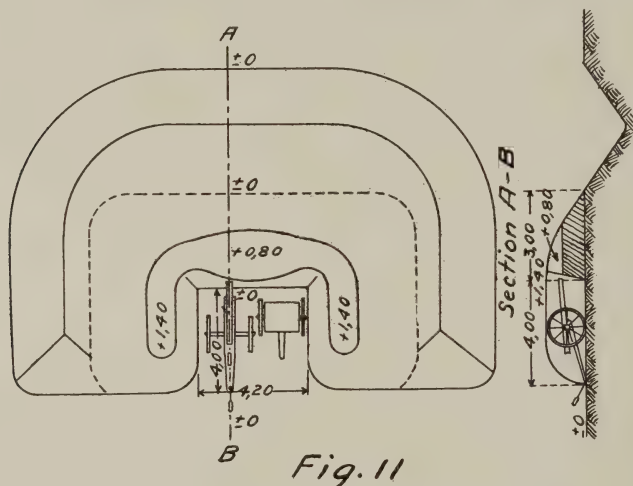


Fig. 11

like those prescribed in the German regulations (Fig. 12) were rarely dug, because the emplacements were too far apart; when they were constructed, they were given a broken line to limit the effect of the enemy's shells. In addition to the trenches for the gunners, they dug trenches behind the battery for the officers; for battery commanders well-covered and well-concealed observation stations were constructed on the nearest height. (Paragraph 94 of the German regulations.) The Russians also appreciated the usefulness of good cover for all the pieces, or groups of pieces, which were advanced to the infantry position to deliver a flanking fire on certain obstacles. This measure was often resorted to when it was not considered possible to reach, during the course of the battle, a position exposed to the infantry fire of the enemy. Naturally, these pieces could not use indirect fire, and the gunners

sought to protect themselves by screens or by panels composed of a wooden frame covered with branches and sand bags.

The German regulations provide no artificial cover for the numerous bodies of troops in rear of the fighting position. In Europe it is expected that sufficient cover will be found, due to the configuration of the ground and vegetation, but on the plains of Manchuria it was often necessary to dig trenches for the battalion and regimental reserves. This was especially necessary when the adversaries remained in close contact for weeks and sometimes for months. In some cases the reserves were provided with cover

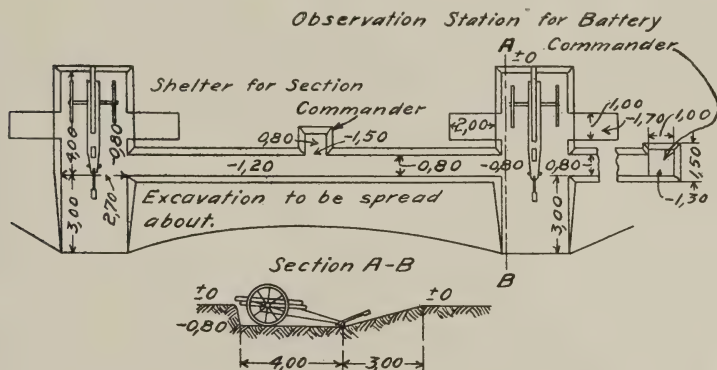


Fig. 12

against artillery fire, especially when they found themselves in the zones beaten by the shells directed against the trenches.

We shall never see a war in Europe like that in Manchuria, still less like that in South Africa. Such extended and such strongly fortified positions will never be reproduced in Europe. Their technical features, arising from the climate and the nature of the terrain, and their moral and physical consequences, arising from the quality of the troops and their leaders, should not be applied without reservation to other wars and other conditions. But every commander should desire that his army profit by the experience of others, and a comparison of the German regulations on field works with the first important Russian work which contains definite conclusions shows that, in spite of numerous differences of opinion, the Germans have been keen and quick to take advantage of the Russian experience.

HYDRO-ELECTRIC DEVELOPMENTS AND HIGH TENSION PRACTICE*

BY

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The present discussion deals with that aspect of hydro-electric developments and high-tension power transmission which appertains to the engineer, to the exclusion of the consideration of such matters as franchise grants, taxation, financial management, governmental regulation, etc.

The province of the engineer is the utilization and combination of available materials according to physical laws for the use of the community, in distinction from the statesman or the educator who have to do with men, and the philosopher who treats of ideas. By this I do not mean that the engineer does not deal with men nor understand and appreciate great ideas, for the high-class engineer must do both, but that his chief concern and ultimate purpose is the combination and control of material things for the use of the community.

The design, construction, and operation of a system for generating power at an available waterfall and transmitting it to a distant market involves a high order of engineering skill, judgment, and experience, for many and diverse engineering problems are involved. Fortunately, the existing successful systems are many, so that our available experience is very satisfactory.

One of the most important and difficult duties falling upon the engineer in such work is the reporting on the feasibility and earning capacity of a projected system. Such reporting is usually very trying, for it is necessary to predict the construction and operating costs of the plant before actual construction or often before it is even designed. It is difficult again, because the ultimate success of the system is quite as likely to depend on some indirect and un-

*Lecture delivered at the United States Engineer School, February 26, 1909.

controllable factor as upon the sufficiency and efficiency of the plant itself. I emphasize this fact, since you may be called upon to report on some hydro-electric project, in which case you should carefully bear it in mind.

As examples of such conditions as might indirectly but still vitally affect the success of an adequately designed and constructed system, I may cite the following:

1. Most streams have annual periods of low water, often times so low that the actual flow is only 1 or 2 per cent of the maximum flow. Evidently, such a stream can ordinarily supply continuous power only up to this minimum limit. This much is usually recognized, but it is often forgotten, that years come once in a while when even this minimum can not be supplied and most of the load must be thrown off or carried in some other manner. The last year was such a year in many parts of this country, and a considerable number of hydraulic plants had to do without much of their usually available power supply; some few were practically shut down.

2. In a cold climate ice may render operation in unusually severe months impracticable, thus having the same effect as low water.

3. Power brought from a long distance through a difficult country may be so unreliable on account of physical interruptions, due to landslides, snow slides, lightning, tropical growth, hostile natives, etc., that it is not satisfactory for the purpose for which it was developed. For example, where such power is used for pumping the water out of mines or for running the blowers of blast furnaces, an interruption of even a half day may mean a very great loss, since the water may drive the men out of the mine and stop work and damage apparatus and supplies, or the furnace may be shut down long enough to cool off, in which case it must usually be torn down to remove the solidified materials at a great loss both of time and money.

These examples are cited to show the importance in studying new projects of considering all the possible causes of failure, and not merely the factors affecting the economy of the design.

In addition to the factors governing the feasibility of a project, the question of possible unprofitableness due to competition from more favorably situated rivals must be considered and further the question whether there is not some different and better way of accomplishing the result sought.

I wish now clearly to call attention to the great responsibility of the engineer in these matters. The expenditure of that portion of

the capital of the community which is available for new work is very largely determined by the reports of engineers, and since the amount of this available capital is strictly limited and mistakes or unwise developments mean corresponding loss to the community, they are of the same nature as a great conflagration. Capital once wrongly expended can not be recovered.

With this introduction, I will pass to the consideration of the most important problems more directly confronting the designing engineer who is laying out a high-tension hydro-electric transmission system.

HYDRAULIC FEATURES

The principal elements of the hydraulic portion of the development are: dams, reservoirs, flumes and canals, pipe lines and penstocks, turbines and turbine governors.

Water powers have a wide range in head and power and the extremes require entirely different treatment. For example, some powers use very large quantities of water at low head, which makes an expensive and in many ways difficult type to develop. The water power used by the famous mills at Lowell, Mass., is of this type; also the water powers of the Missouri River Power Co., at Helena, Mont.

There are in contrast to these the very high head plants, usually found in mountain places, where a relatively small amount of water will develop a large amount of power. It will be remembered that the horse power theoretically available in a stream is equal to the head in feet multiplied by the weight of water passing per second divided by 550. This high head type of power is a favorable and cheaply developed type. A good example is the Colgate plant of the California Gas and Electric Co., which has about a 900-foot head, and develops a large amount of power. Some other plants have much higher heads running up to 2,000 feet. Where still higher heads are available, as sometimes occurs, two plants may be installed, dividing the head between them. The Necaxa system of the Mexican Light and Power Co. has available a total of somewhere near a mile head. This will probably be developed in three stations, severally using the same water one after another.

There are other plants having intermediate heads, some of which are very favorable for economical development. A conspicuous example is the Niagara Falls development, where the head is moderate and the amount of water nearly unlimited. The Zambesi

Falls, in Africa, of which a good deal has been heard, is another example, having a head considerably higher than Niagara. Again, in some cases, the head is found concentrated at one point, as at Niagara, but in many more cases it is distributed along the stream, sometimes over a distance of a number of miles. In this case, to actually utilize the power, the water must be carried at the high level into the neighborhood of the low level, or the pressure conserved in pressure pipes. These different types of development must be carefully borne in mind in the consideration of the characteristics of the various elements of the hydraulic systems.

DAMS

The two salient characteristics of a dam are, first, its power to resist being carried bodily away at time of freshet or by the normal water pressure, and, second, its water-tightness.

It is easily seen that with considerable heads, since the water pressure on the upstream side equals .433 pounds per square inch for every foot of head, the resultant total pressure on a dam, tending to overturn it, is enormous. On a dam area 10 feet high and 100 feet long under 100-foot head the pressure would be over 3,000 tons. The great problem is to make a structure that can resist this strictly mechanical strain. The materials usually found in dams—stone, timber, and earth—are such as to have little tensile strength, and hence can not be designed or built up as beams and trusses to carry a load. In most cases dead weight is relied upon to hold the dams in place. But this very item of dead weight requires adequate foundations for support, especially in virtue of the presence of water in the ground below the dam, caused by the water above, which tends to loosen the earth material and disturb the foundation. In all cases where the head is at all considerable it is highly desirable that the dam shall be founded on rock or impervious hard pan. This sometimes requires carrying the foundations down many feet, making a dam perhaps double the height of the available hydraulic head.

By giving the dam a base wide in proportion to its height the resisting moment of the weight of the dam in preventing overturning is increased, and this is a common expedient, but it increases the volume of the dam and the cost. It is not sufficient to resist overturning alone, for the dam may be pushed directly downstream, if it is not set deep and firm in the bottom or otherwise secured.

On account of the great weight and cost of dams for high heads where dead weight alone is depended upon to hold the pressure, various schemes have been proposed and tried to get strength in some other way. Where the length of the dam is short, it is possible to construct it in the form of an arch, convex upstream, and founded solidly against firm rock on the sides. Such a dam will resist the water power, as a bridge arch resists loads on the bridge, far in excess of its own weight.

Another form of much wider applicability is the so-called Ambursen dam, which is a dam of the usual masonry form, but formed as a monolith of reinforced concrete. This dam has an unbroken outer surface exposed to the water both upstream and downstream, but this skin is supported below by vertical ribs or buttresses underneath, which construction permits passages through under the curtain of the dam and greatly reduces the weight required. Then to assist in preventing overturning, the upstream face of the dam is made to slope for some distance and the upstream edge or heel is made water-tight to the bottom, so that there can be no hydrostatic pressure underneath, and the weight of the water in the reservoir will hold down the dam. This type of dam has many advantages, but has not yet been in use a long enough time to determine all its possible limitations.

It is manifestly desirable that a dam be water-tight, but this will not necessarily always be the case, even with good construction. The difficulty with leakage is not only the loss of water, but the danger of gradually washing away and undermining the foundation of the dam. In spite of all precautions, water will sometimes leak around a dam through some crevice in the earth formation. With dams of low height where the available head comes largely from falls or rapids below the dam, sometimes called diverting dams, many simple and inexpensive forms may be used. One of the commonest is a timber crib filled with rock to hold it down and covered with planking.

A further difficulty with dams is their protection against ice and débris at times of floods; cakes of ice and trunks of trees carried along at good speed going over a dam of any considerable height will evidently give the mechanical structure at the bottom a severe pounding. Dams are usually given a curved downstream surface or a relatively slow incline to relieve this strain. There is, further,

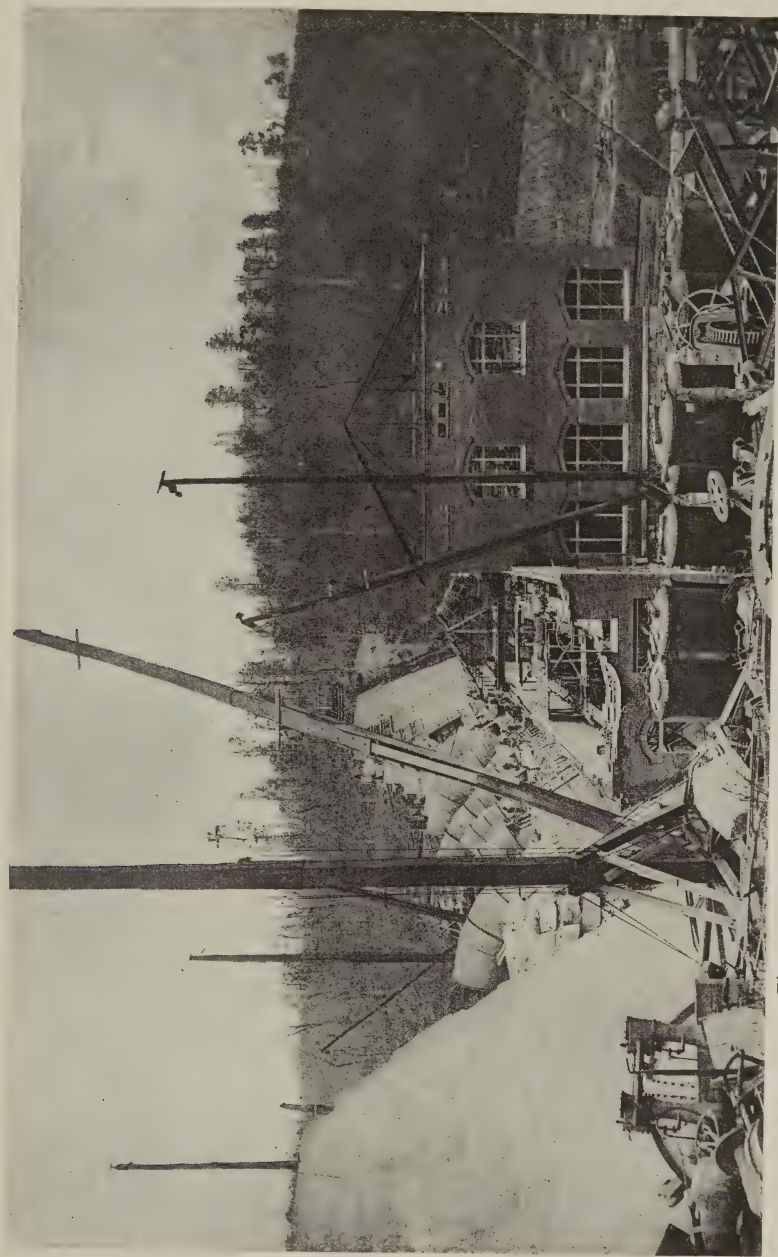


Fig. 1. Dam and penstocks in course of construction, Southern Power Co.

a strong tendency for the water overflowing the crest to undermine the lower edge or toe of the dam.

RESERVOIRS

The storage of water in hydraulic plants may be very important or not, according to conditions. It is usually impossible to store enough water to run more than a few hours or, at most, a few days, in large plants of low head, on account of the enormous capacity required. But with high-head plants storage may be a very important item, as a small quantity of water represents a great deal of power. It may be possible to store enough water to last a month or two in some cases, which would manifestly add greatly to the value of the water power. In plants where the same water is used in a number of stations on the same stream, one reservoir will serve for all the stations, thus greatly reducing the proportionate expense.

It is, of course, not necessary that the reservoir be at the dam at which the water for the water wheels is diverted; it may be many miles up the stream, or several reservoirs of small size may be provided on the tributaries of the stream, as may be most feasible.

In any case, there should be enough water stored to run the wheels at their maximum for an hour or two, to be able to care for daily peak loads.

It must be borne in mind that the only storage available in a reservoir is that lying between the maximum level that can be held in the reservoir and the minimum level to which it can be drawn down. This may leave a great deal of water in the reservoir that is never used.

FLUMES AND CANALS

Flumes and canals serve to carry the water from the stream at the high or dam level to the power station, usually in the neighborhood of the lower stream or tail race level, sometimes a distance of several miles. Where the country is fairly level, canals are usually used and are reasonably inexpensive, satisfactory, and reliable. In mountain country, however, such as usually supplies high heads and small quantities of water, such canals become very expensive and subject to interruption from land slides, rolling stones, heavy freshets, and such disturbances, and wooden flumes are often substituted. When it is remembered that such flumes must be carried along the precipitous side of a mountain for miles, the difficulty of construction and danger of interruption becomes manifest. Most

of our far western power developments are of this sort. In such case, the water is usually carried either in open wooden flumes or enclosed wooden or steel pipes. These are much cheaper than canals and more easily constructed, at least for side hill work. But a flume deteriorates rapidly, lasting ten or fifteen years, and is, of course, open to interruption by slides and falling débris of all kinds. With such an arrangement it is highly desirable, but usually impracticable, to have a storage reservoir at the power house end of the flume to carry the load while repairs can be made on the flume. These flumes are made of small dimensions by using high velocities

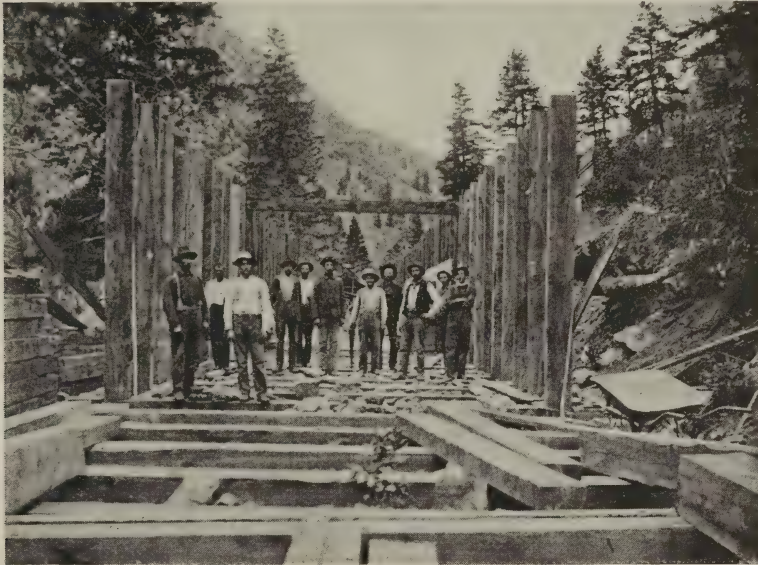


Fig. 2. Building a large wooden flume in the west.

of flow; as high as 5 to 7 or 8 feet a second. This causes a considerable loss in head.

It is necessary to carefully grade a flume to produce the necessary fall to give the right velocity of water at all points and to prevent overflowing at any point, especially on curves, where the water will pile up on the outside face of the flume; and also to prevent high spots which would reduce the capacity of the flume by reducing its effective section at these spots.

With pipe lines, however, this is not necessary, as the pipe will preserve the static head and the contour of the country can be followed, provided the original level be not surpassed. It is well also

not to drop the pipe too low, as a reinforced construction is required where the pressure gets high. The pipe line will usually be run on about the same level as the flume.

Of course, at the power station itself a penstock must be used, suited in size and strength to carry the water and withhold the pressure of the actual total head.

Where steel pipes are used there must be provision made for expansion and contraction, and this is usually a troublesome matter. Wooden pipes are much used in the West. These are built up of overlapping staves, somewhat like a barrel, and bound with hoops. This type is readily transported, is cheaper than the steel in most cases, and has no temperature expansion difficulty to consider.

In view of the enormous weight of water in the pipe line, if this have several miles' length, the inertia of the water is enormous and changes in its velocity can be made only very slowly. Any rapid closing of valves at the receiving end would, inevitably, result in the bursting of the pipe, were no means of protection provided. The seriousness of this matter will be easily manifest. Protection is secured by relief valves placed at suitable intervals, which will open outward when the pressure exceeds a reasonable minimum. These relief valves may be either spring controlled or may consist of stand pipes open at the top, out of which the water can flow as long as the pressure is dangerously high.

Penstocks on high heads should be provided with air inlets at the top, or, rather, should be open to the air at all times, for if a gate valve be closed at the top, stopping the flow of water when there is no air inlet at this point, the water falling away down the pipe toward the lower end will leave a vacuum at the top which will collapse the pipe, as it is not designed to withstand an inward strain. This accident has happened, and is very vexing, to say the least.

It is further clear, in view of the considerable weight of the water in a pipe or flume, that the foundations for the trestle work on which they are carried much of the way in side hill work are a troublesome and important item.

TURBINES

The principle of operation of the hydraulic turbine is pretty generally understood. It is easiest seen in the so-called "Pelton" type, which is largely used on high heads, such as 200 or 300 feet, or higher. This turbine consists of a series of curved buckets arranged on the periphery of a wheel and receiving water from a

jet from a nozzle on the lower side, which jet of water strikes the wheel tangentially. As the water issues in this jet, all its original potential energy has been converted into velocity or kinetic energy, which it is the function of the wheel to absorb. The buckets are so shaped that if the wheel stood still the water would be deflected 180 degrees around inside the bucket and thrown directly backward, with, of course, approximately its original velocity. On the other hand, if the wheel revolve at such a velocity that the buckets pass at the same speed as the water in the jet, the water will not be deflected at all, and neither in this case, nor in the case in which



Fig. 3. A wooden pipe line in course of construction.

the wheel stood still, would there be any power taken from the water. On the other hand, if the wheel revolves at half the latter velocity—that is, half the jet velocity—the water would be deflected by the buckets so as to be thrown backward, but in virtue of the half speed of these buckets would have practically no velocity at all after deflection, and would fall directly downward out of the way. In this case, the energy of the water is taken up by the wheel. This is the ideal condition of the “Pelton” wheel. As a matter of actual practice, it is very important in getting good efficiency in such a wheel to have a very smooth and perfect jet and exactly the right shape of buckets, as otherwise eddies will be produced in the water and energy lost.

The regulation of such a wheel to give constant speed under

varying load may be obtained by deflecting the jet so that only a portion of it touches the wheel as the load becomes light, or by cutting down the jet area by introducing from behind a round, tapering point or plug in the center of the jet which will not disturb its smoothness. On the very high heads it is almost impossible to control the speed by varying the amount of water flowing at the wheel, on account of the inertia of the water.

The "Pelton" type of wheel runs at very high velocities and is very small in size in proportion to its output. It is also quite satisfactory in regard to its efficiency, which may run as high as 80 or 85 per cent.

Turbines used on lower heads are mostly of the completely enclosed types and operate on the same general principle as the "Pelton." Here, the water is deflected by stationary vanes in entering the turbines so as to strike blades or buckets on the revolving part at the proper angle. In virtue of the velocity of these revolving vanes, the energy is taken out of the water either by allowing the water to spout from the revolving part, in which case the revolving part will move backward at somewhere near the speed with which the water spouts forward from it, leaving the water to fall away practically without motion and thus give up its energy to the wheel, or the water may be given a considerable velocity before it reaches the revolving parts, which then act like the buckets of the "Pelton" wheel, or these sorts may be combined.

The size of the wheel must, evidently, depend greatly on the head, for this determines the volume of water to be passed for a given power; and, further, the high head wheels run at higher speeds and are hence naturally smaller. The circumferential speed of the wheel is largely determined by the spouting velocity of the water, and therefore the number of revolutions can be controlled for design purposes only by variations of the diameter of the runner. This variation can, obviously, be permitted only within rather narrow limits, so that the speed of water wheels is more or less closely fixed by their head and capacity.

The full-load efficiency of water wheels at their best runs somewhat over 80 per cent, but the conditions must be favorable to secure this efficiency. In ordinary cases the efficiency may often actually be 10 or 15 per cent less.

The governing of turbines on varying loads has been found a difficult matter in the past. The great difficulty arises in the inertia of the water column that is feeding the wheel. When there is a sud-

den change of load and it is necessary to suddenly change the amount of water supplied, this can not readily be done, since the change is resisted by the inertia of the water. On this account the governor, finding that the speed of the wheel is not reduced, goes on trying to close the gates, and when the inertia of the water is finally overcome, the governor has closed the valves far beyond the point of equilibrium, and the speed is too much reduced, and the governor then tries to speed up the wheel with the same tendency to overrun. This difficulty has been pretty well overcome by ingenious arrangements of governors, in which the tendency to overrun is balanced by dashpots and the action otherwise regulated.

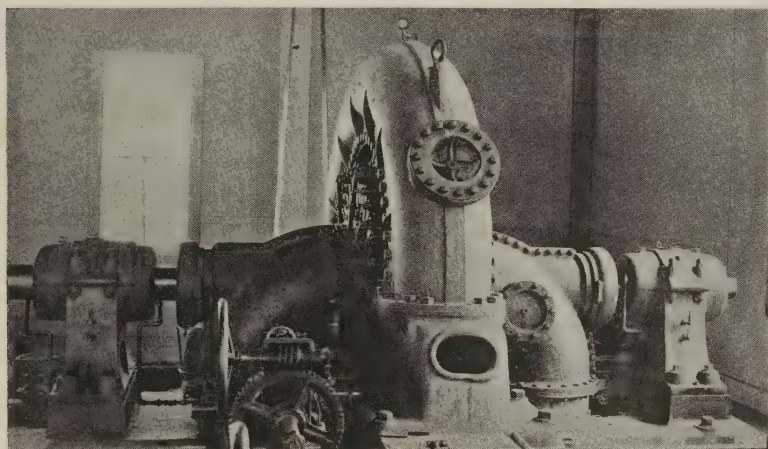


Fig. 4. Francis turbine, medium high head.

There is a further difficulty, in that the valves and moving control parts of large turbines are very heavy and much power is required to handle them, especially as there is a tendency on the part of the incoming water to make them "bind." For this reason turbine governors act through relays and do not control the valves directly as in steam engines. These difficulties are of much less moment in high-head plants than in low-head plants.

ELECTRIC FEATURES

The more important electric features of the hydro-electric system are: generators; switchboards and switches; transformers, raising and lowering; and the transmission line.

Generators.—The generator characteristics are not particularly

different in a hydro-electric plant from any other sort of electric power system.

As usual in all work, it is necessary to have a generator adapted to the prime mover available, and since the turbine design does not permit of very great ranges of speed, the generator speed will be chosen to correspond. It is customary to design the turbines and generators to stand mechanically the full speed that can be generated by a runaway turbine, since this speed is always less than twice the normal speed and the critical condition can be conveniently met. In the case of steam engines, no such requirement is made, for it is not possible to make engine and generator stand runaway speed, since there is no definite limit to the runaway speed of the steam engine.

Switchboards and Switches.—The switching arrangements of the hydro-electric system are not radically different from those of other power stations and will be only briefly discussed.

The switching apparatus is usually the cause of more trouble in a transmission system than any other feature, unless it be the line. The arrangements should be as simple and the switches few as possible. In small plants, as far as practicable, all parts should be either directly in view or as quickly accessible as possible, for at times of emergency the most important consideration is for the operator to know as soon as may be just what has happened and what apparatus he can safely use. If the apparatus is placed in different rooms and covered up, it will often take a considerable time in case of accident to find out what has actually happened and the resumption of operation be so much delayed.

In large plants it is impracticable, however, to have all the switching and other apparatus in sight, and remote control is usually substituted. By this system the switches are magnetically operated either by a solenoid or a motor, and the controlling circuits are brought to a central control board, so that they are all under the hand of one operator. It is usual, as well, to bring indicating circuits to the same control board to show what the actual position, whether open or closed, of the various switches is at all times. Machines are ordinarily started, paralleled, adjusted, and shut down from the control board. This requires, of course, the presence of a man at the generators and wheels or engines in communication with the board operator.

It is very essential to protect the switching apparatus in such a way that a failure of one device will not spread to another through

any are that may be formed. This accident will happen surprisingly easily, and frequently what might have been merely a small disturbance, confined to one circuit, may be thus made a general shut down, with much damage.

It is highly desirable as well to have some way of positively cutting off the circuit in the case, as sometimes happens, that a switch fails. This is not an easy matter in large plants, and no general rule as to the best arrangement for securing the result can be given.

Transformers.—Transformers used in high-tension transmission plants are practically always of the oil insulated type and are very often water cooled. This latter type is rather cheaper than the natural draft type, but is not so efficient. The gain in cost by cooling through water and thus allowing larger heat losses without undue heating is more important than the accompanying loss of efficiency. Cooling water is not always available.

It is usually considered the best practice to provide a single set of transformers for each outgoing or incoming line at any station. By this means switching is a good deal simplified and, further, the capacity of the transformers can be used to better advantage. Another very important advantage is the possibility of separation of lines on the high-tension side by paralleling the transformers only on the low-tension side, so that disturbances on one line will not be likely to disturb another line. This is an important operating advantage.

Lines are universally made three phase on account both of the economy of transmission and the economy of apparatus connected to them, and, further, on account of the possibility of using induction motors.

The transformers may be connected either in star or delta, or by the connection sometimes known as "V." The most usual practice is to connect the high-tension windings in delta, since when three transformers are so connected the load may still be carried when one transformer is disabled and cut out. The other two will carry within about 10 or 15 per cent of their combined capacity; that is, nearly two-thirds of the total capacity of the three transformers. On very high-tension plants the construction of the transformer, delta connected, becomes somewhat more difficult than that of the transformer wound for star connection on account of the fact that the former arrangement requires 1.732 times as high a voltage. Then, in case a complete spare line or set of transformers be pro-

vided, the possibility in the delta connection of using two transformers without the third becomes of less importance.

A number of plants have the star connection on the high-tension side. This arrangement has been used a number of times when it is intended to run at a lower voltage at the starting of the plant and at some future time to raise the line voltage. By starting the transformers with the delta connection and then connecting the same transformers in star, the line voltage will be raised by the factor 1.732 and the efficiency of transmission thus much increased. The capacity of the transformers is the same in either connection.

In some cases of small lines and temporary work, or in places where the load is expected to increase later, two transformers may be connected in "V;" that is, connected the same as in delta, with one of the three transformers omitted. Then later, as the load increases, a third transformer may be added. This is not a wise arrangement, except in special cases where the transformers are not fully loaded, as the transformers are working at a disadvantage and have their capacity, efficiency, and regulation reduced.

Raising transformers should always have their primary windings connected in delta, or, if necessary, in "V," for otherwise a short circuit on one high-tension transformer winding will throw the voltage of the generator wholly on the other two transformers, raising the line voltage by the factor 1.732. This difficulty can, if necessary, be eliminated by connecting the common point of the star of the transformer primaries to the neutral point of the generator. This arrangement will usually be found undesirable. It tends to cause triple frequency circulating currents with generators in parallel.

Three-phase transformers are sometimes used and are growing in favor. Transformers may be used, of course, to change from two phase to three phase.

There are a number of more or less important points that might be discussed in connection with the transformers, but I will touch on only one more. The great body of oil necessarily used with the large and numerous transformers of a good sized station is a very serious fire risk. The oil used is very hard to ignite, and there is only a limited danger of this, even from short circuits in the transformer itself; but if once a fire does get a start in the station, so that the oil tanks are injured or their foundations destroyed, the result is to pour fuel oil all over the station, with very disastrous results. This accident has happened a few times, with practically

the destruction of the whole station. The seriousness of this, even neglecting the money loss, in the stoppage of the service while a new station can be built, will be readily evident.

It is customary in large plants to provide boiler iron tanks that will stand great strains mechanically and to cover them and provide a pipe connection for emptying out the oil without exposure to the air in case of necessity. It is, of course, necessary to turn the oil into a sewer or otherwise discharge it far enough away to avoid danger of its then igniting.

To be concluded.

MANGANESE STEEL CASTINGS

BY

CHR. HOLTH, M. E.

Junior Engineer

In the last few years different parts of machinery which are subjected to great abrasive wear have been cast in manganese steel, which material, if correctly manufactured, possesses remarkable hardness, combined with great tensile strength and ductility.

The experience gained by the writer in the inspection of this material during 1908 and 1909 for the Isthmian Canal Commission may be of value to others, and is herewith freely given, so far as permissible, without betraying any secret process that the manufacturers would not care to have revealed.

As this material seems to be too little known, a short, practical outline of the process of its manufacture, without going into any scientific details, will be given in the following.

By the term "manganese steel castings" as here used is understood an alloy of iron, manganese, and carbon, containing about 12 per cent of manganese and from 0.9 per cent to 1.25 per cent of carbon.

This alloy is very hard and can not be machined, to any great extent, with any steel tool, as will be understood when it is stated that it will take from one and a half to three or more hours to drill a hole 1 inch in diameter through a 1 inch thick casting with a steel drill specially prepared for this purpose.

The machining or finishing of castings is done by a grinding process, in which the emery wheel has been found to give the best results.

The great hardness of the alloy, which makes it so valuable in resisting abrasive wear, also limits its practical use. Manganese steel castings are at present extensively used for stone-crusher jaws, dipper lips and teeth for dredges and steam shovels, toothed gearing, bushings, railroad frogs, wheels and switches, burglar-proof safes, etc.

The Isthmian Canal Commission, in ordering castings made from

this material, gives the following specifications to govern the manufacture:

Manganese steel castings shall contain not less than 11 per cent nor more than 13½ per cent manganese.

All castings are to be given the proper heat treatment required for the use to which they shall be put, and to develop the bending test as follows:

Test specimens ½ by ¾ inch cast under the same conditions, and given exactly the same heat treatment as in the castings themselves, shall bend cold around a diameter of 1 inch to an angle of 180° without cracking or exhibiting other signs of failure.

Castings shall be true to drawings, free from blowholes, flaws, and cracks. Surfaces marked for rough finish (Rf) may be either smooth cast or ground smooth and fairly true. Where accurate finish is called for (f) the finish is to be accomplished by grinding accurately to dimensions given on drawing; smooth cast finish will not be sufficient.

All holes are to be cored accurately so that castings check closely with drawings when cool. No cast-in plugs will be allowed in any of the castings. Castings showing signs of being treated with a cement or otherwise to fill up cracks or holes will not be accepted.

Manganese steel castings are very dense and practically free from blowholes; but they may contain large and injurious cinder pockets.

The cold bending test prescribed in above specifications for treated steel will be satisfied if carbon contents of steel are below 1.25 per cent and phosphorus not exceeding 0.9 per cent. Ultimate strength, yield-point elongation, and reduction in area for specimens tested to destruction will vary with the chemical contents and with the temperature under which the steel is poured. I have not succeeded in getting any physical test of this steel outside of the bending test. Manganese steel at yellow heat will stand forging very well, and the following results of physical tests taken from rolled bars may be interesting. The bars contained about 12 per cent manganese. Tests were made November 17, 1909, in the testing laboratory of Robert W. Hunt & Co., Chicago, Ill.

Original dimensions.....	.858	.861
Dimensions after fracture.....	.695	.693
Original area, square inches.....	.5782	.5822
Fractured area, square inches.....	.3794	.3772
Elastic limit, pounds, actual.....	34,380	33,420
Maximum load, pounds, actual.....	72,530	72,570
Elongation in 2 inches.....	.73	.77
Elongation in 4 inches.....	1.45	1.46
Elastic limit per square inch.....	59,460	57,400
Tensile strength per square inch.....	125,440	124,650
Per cent elongation in 2 inches.....	36.50	38.50
Per cent elongation in 4 inches.....	36.25	36.50
Per cent reduction of area.....	34.38	35.21
Character of fracture.....	S	S

At white heat the steel is brittle, and the feeders and risers on poured castings can easily be broken off when the steel has this color.

OUTLINE OF PROCESS

Pouring.—Molten ferro-manganese is added to Bessemer, or other process steel in foundry ladle immediately before pouring.

The proportioning of the various elements of which alloys shall consist is regulated in the same precise manner as in use in ordinary steel foundries.

To obtain the required percentage of manganese in the steel seems to give less trouble than the proportioning of carbon, for which element manganese apparently possesses a strong affinity.

Of several hundred heats of manganese steel which I have seen poured at the plant of the American Brake Shoe & Foundry Co., at Chicago Heights, Ill., not one was rejected on account of its contents of manganese. The manganese steel is poured into the moulds at a very high temperature (from 2,800 to 3,600° F.), and it casts very dense and free from blowholes; the manganese seemingly having the same effect in this alloy as silicon and aluminum in other cast steel. It runs very freely in the moulds, and castings come out nearly as nice, smooth, and sharp as those made from brass or tin.

Because of the high temperature at which this steel is poured, the foundry ladle used can not very well be constructed with bottom tap hole and stopper, but must be poured by tilting the ladle; and it is necessary to exercise the greatest care to prevent the slag covering the steel from being poured into the moulds.

Heat Treatment.—When castings are removed from the moulds, they are all more or less brittle; and all acceptable castings are now placed in an annealing furnace and there heated to a high temperature, about 2,000° F.

In this process pyrometers are used; but the skilled operator depends more upon his eye and the color to which he wants his steel heated.

From the furnace the castings are taken directly to be quenched in a basin of cold water, brine, or other solution, the composition of which may vary according to different manufacturers' formulæ.

The result of this heat treatment is that the previously brittle castings now become ductile and tough.

Finishing.—The castings are now ready for the cleaning and

finishing processes, which are all practically accomplished by grinding with emery wheels run at their maximum permissible speed. For the removal of the larger protuberances, feeders, risers, and fins, the oxygen gas process has been found to be very effective. Long castings, such as racks, switches, etc., which have sagged and bent in the annealing furnace, are straightened either by drop-hammers or other devices.

FACTS TO BE NOTED BY INSPECTORS

The various parts of the process—the blowing of the steel in the converter, the melting of the ferro-manganese in the crucible, and the heat treatment of castings—all look very simple, but can not be accomplished without highly skilled operators.

As stated above, it is not the intention here to go into details of the different operations, which may vary more or less with different manufacturers. The linings of converters and ladles, and the use of green and dry sand with different facings, are practically the same as in ordinary steel foundries.

Attention is, however, invited to the phenomenon of skin cracks appearing in some test bars, which is explained below.

The castings and test bars (if test bars are not attached to castings) to be treated are so arranged in the furnace that all are heated to practically the same degree; they are then taken out of the furnace and quenched. It may happen that one or more test bars, if exposed to the air for some time before quenching, will show surface or skin cracks when subjected to the bending test, while other bars from the same mould or flask will bend perfectly, simply because they were not allowed to cool off in the air before being submerged in the fluid. For this reason it is recommended that if test bars are attached to castings, they should be at least three in number. If test bars are cast separately, there should be not less than four in a flask.

Manganese steel containing about 12 per cent manganese is practically non-magnetic, a fact which should be borne in mind by the inspector taking sample borings for chemical analysis. On account of the extreme hardness of this steel, it often happens that the drill bit will break during the boring of a sample, and that small pieces of the bit will be mixed with the manganese steel drillings; and if these are not separated, the analysis may give an entirely erroneous result. For this reason a strong magnet should be suspended from 1 to 3 inches above the borings; this will attract to itself all the

carbon steel particles that may be mixed in, leaving the manganese steel undisturbed.

The shrinkage in cast steel is always greater than in cast iron, and it varies with the temperature. Castings poured from the hottest steel have the greatest shrinkage, but they are the smoothest. Therefore, in the case of long manganese steel castings, as, for example, racks and switches, having holes cored for riveting to some machine part, it is of importance that the steel be poured at the same temperature for all racks of the same pattern, having first ascertained the amount of shrinkage for the particular temperature at which the steel is to be poured.

Castings in manganese steel can, by special effort, be made remarkably exact, and gearing may be cast practically as close as cut gear. This practice, however, is not always to be recommended, as it would be rather expensive in case any chipping or grinding of the finished gear should be found necessary; and it is, therefore, advisable to have even a little more backlash in these gears than is used in cast iron.

The American Brake Shoe & Foundry Co. tried, by special effort, to make their castings of racks for steam shovels (ordered by the Isthmian Canal Commission) to come within a variation of one-eighth inch in 10 linear feet. They succeeded better than anticipated; but after an allowance of 1-64 inch per linear foot, or 5-32 inch in 10 feet, was granted, practically all racks cast came within this limit.

For standard specifications for castings, where accuracy is not required, a variation of 1-32 inch, or even 1-16 inch, per linear foot is recommended; as this will, in all probability, result in lower prices bid by contractors and be a better commercial proposition for all parties.

In the designing of castings it should not be forgotten that the machine finishing of this material is one of the reasons for its high price, and finished areas must, therefore, be reduced to a minimum.

Cast-in centers of soft steel are often successfully used in wheel hubs and other places where a bored hole is required.

The heat treatment is generally supposed to penetrate about $1\frac{1}{2}$ inches; and for this reason castings should not be made thicker than 3 inches in any place. By special effort this treatment can be made to penetrate $2\frac{1}{2}$ inches.

In taking samples for chemical analysis it does not seem to make any appreciable difference, so far as manganese or carbon are con-

cerned, whether the borings are taken from the test bar before or after heat treatment, as will be seen from the two analyses shown below, given to me by the courtesy of Mr. W. G. Nichols, general superintendent of the plant.

"American Brake Shoe and Foundry Co.,
Chicago Heights, Ill.,

CHEMICAL LABORATORY.

	Test Bar.	Carbon.	Manganese.
Before heat treated -----	I-7	1.157	11.52
After heat treated -----	I-7	1.150	11.49
Before heat treated -----	I-8	1.187	12.14
After heat treated -----	I-8	1.181	12.16

(Signed)

C. C. COBLE,
Chemist."

For various canal and river works, where castings and special gearing may sometimes, on account of ice and sand, be strained beyond expectancy, it seems to me that manganese steel is the ideal material to be used.

Before designing castings it may, however, be advisable to have the water in which they are to be submerged analyzed as to its purity, as it is claimed that steel containing manganese will corrode quicker than carbon steel or pure wrought iron, particularly so in waters contaminated with sewage or other sulphurous impurities, or waters showing an acid reaction.

This can probably be accepted as the result of electrolysis created between different particles of iron and manganese, both being present in a mechanical mixture in the alloy.

The number of successful manufacturers of manganese steel is at present limited, and the scrupulous secrecy maintained by some of them with regard to their individual process of manufacture indicates that this is yet in its infancy, and has not yet passed the experimental stage.

The fact that the price per pound of manganese steel castings, manufactured according to specifications similar to those issued by the Isthmian Canal Commission, has in the last two years been reduced some 25 to 50 per cent, seems to prove this assumption to be correct.

To assist in estimating costs, it may be stated that rough castings weighing 200 pounds or more can be figured at from 12 to 18 cents per pound. For smaller castings the price will be somewhat higher. Finished castings may cost 2 or 3 cents more per pound. A more

accurate figure for the cost per square inch of finishing surfaces can probably be ascertained from the Isthmian Canal Commission, which has a grinding plant at the Isthmus.

Walker Keith Armistead

Walker Keith Armistead (see frontispiece) was born in Virginia about 1780. He was appointed a cadet at the United States Military Academy May 1, 1801, from which institution he graduated March 5, 1803, and was promoted Second Lieutenant in the Corps of Engineers. His promotions thereafter were as follows: First Lieutenant, June 11, 1805; Captain, October 30, 1806; Major, July 23, 1810; Lieutenant-Colonel, July 31, 1812; Colonel and Chief Engineer, November 12, 1818. On the reorganization of the Army he was appointed Colonel of the Third Artillery, June 1, 1821, and was brevetted Brigadier-General, United States Army, November 12, 1828, for faithful service in one grade for a period of ten years. From 1808 to 1811, he was Superintending Engineer of the defenses of Norfolk, Va.; and in 1811 was on duty at the Military Academy. In the War of 1812 he was Chief Engineer of the Army on the Niagara frontier; and in the autumn of that year he was engaged at Fort Niagara during its bombardment. In 1813 he was Chief Engineer of the forces for the defense of Chesapeake Bay, and was Superintending Engineer of the defenses of Chesapeake Bay and its tributary waters from 1814 to 1818. On November 12, 1818, upon the resignation of Col. Joseph Gardner Swift, he was appointed Chief (or Principal) Engineer, United States Army, in command of the Corps of Engineers and the Engineer Bureau and was ex-officio Inspector of the United States Military Academy. After the reorganization of the Army, as Colonel of the Third United States Artillery, he was stationed at Fort Washington, Md., 1821-1827; Upperville, Va., 1827; Boston, Mass., 1828-1830; New London, Conn., 1831-1832; Upperville, Va., 1832-1834; Fort Monroe, Va., 1834-1836. He served in the Florida War against the Seminole Indians in 1836-1837, and was on court-martial duty from 1838 to 1840. In 1840 and 1841 he commanded the troops of the Florida Army against the Seminole Indians. From 1841 to 1843 he served on Board duty, and in the following year was in command of the Third Artillery at Fort Moultrie, S. C. He was granted sick leave in 1844, and died at Upperville, Va., October 13, 1845.—*From Cullom's Biographical Register of the Officers and Graduates of the United States Military Academy.*

RIVER AND HARBOR WORK FROM A MILITARY POINT OF VIEW

A letter from the Chief of Engineers, United States Army, to the Chairman of the
Military Committee of the House of Representatives

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, March 7, 1910.

MY DEAR MR. HULL: In connection with our recent conversation regarding the character of certain duties devolving by law upon the Corps of Engineers, I beg to submit to you the following:

The question was in reference to the river and harbor and similar work, which is at times, in my opinion, improperly designated as civil work.

I would present the claim that such class of work, which has since the organization of this Government been made by law a part of the duties of an essentially military corps of the army, is essentially military work, and the designation "civil work" is a misnomer, arising partially, at least, from the fact that it is separated from the Regular Army estimates and provided for in appropriation acts other than that commonly designated as the act for the support of the Military Establishment.

It would appear equally proper to class as civil work that of the Subsistence Department, which buys and furnishes subsistence stores; that of the Quartermaster's Department, which builds quarters, furnishes supplies of various kinds, and mobile transportation for the army; that of the Ordnance Department, which supplies arms, powder, etc.; that of the Medical Department, or the Judge-Advocate's, or Adjutant-General's Department, as it is to class as civil work the construction of harbors for our navy and for transports, and the construction of lines of water communication for the movement of army supplies and troops.

The Corps of Engineers, in peace and in war, have ever been kept at work up to their capacity on duties essential to the military strength of the United States.

It will be remembered that engineer officers not only do so-called civil engineering work, but also have at all times work with troops,

military surveying, and various duties pertaining strictly to the purely military side of their profession, and in time of war have their place in the field as a part of the fighting line, which brought to the corps during the civil war the destruction of one-tenth its strength through death in battle or fatal wounds.

Since remote times the construction of roads and means of transportation, harbors and canals, have been among the most essential military works.

The roads constructed by the army of Xerxes, including the ponton bridge across the Hellespont, the Roman military roads in every part of the Roman Empire, such as the Appian Way, roads in Spain, in Gaul, and in Great Britain, and the harbor improvements at Ostia, Rhodes, London, Alexandria, Piræus, Carthage, and Tyre, etc., for the ancient fleets of Rome, Greece, Phœneicia, and Carthage, are samples of military and naval roads and river and harbor improvements, and we have all struggled with unraveling Cæsar's account of his bridge over the Rhine, and with the accounts of the road construction for the armies of Hannibal over the Alps.

The uses of our rivers during the civil war and their influence as means of transportation and communication are still fresh in our memories.

On the Atlantic seacoast, from Maine to the Rio Grande, and on the Pacific, from Bellingham Bay to Lower California, with the exception of Narragansett Bay on the Atlantic and Puget Sound on the Pacific, there are few or no harbors or channels leading thereto which in their natural or unimproved condition would allow the most modern battle ships safe entrance or passage. Without the work of the military engineers of the United States, carried out under river and harbor acts, our modern fleets of battle ships could not reach the naval stations, yards, and docks at Boston, New York, Norfolk, Charleston, Key West, Pensacola, or New Orleans, nor enter any important seaport on the Atlantic Ocean.

The improved channels on the Great Lakes, and rivers, such as the Hudson, Ohio, Mississippi (channel and mouth), Alabama system, etc., play an important part in the economical transportation and supply of food, fuel and equipments for our armies and navies.

Without the river and harbor work we could have no modern navy for lack of harbor and sheltered dock yards; we could not have economical transportation for coal and naval supplies, or for military stores.

The Panama Canal, the proposed Delaware and Raritan Canal, the Delaware and Chesapeake Canal, the Albermarle and Ches-

peake Canal, and the channel of the intracoastal waterway, all now under construction or survey, are essentially military works.

It is the opinion of the Chief of Engineers that the Corps of Engineers should be maintained as a strictly military organization, that all its officers should be educated and trained not only in the various branches of its engineering work, but also in its so-called strictly military duties; that in its engineering work equally as well as in its purely military work great advantage comes from its discipline and military organization, from its simplicity of purpose, and independence and freedom from all purposes other than the interests of the General Government which it is serving, and further, that its officers should be at any time, in peace or war, available and eligible for any and all of the varied duties to which they may be called.

The thought here expressed carries with it the proposition that the Corps of Engineers should be reserved for those who have received a thorough education and training in their varied duties by coming in at the bottom under proper restrictions and passing through a thorough training.

This is no discrimination against the civil engineer. It will be remembered that the only work open to members of the corps is in its own limited sphere of duties, while even in the Government service itself there are many positions open to civil engineers at large, such as the Geological Survey, the Coast and Geodetic Survey, the Reclamation Service, civil engineers in the navy, and in several other branches of the Government departments, and beyond all this the vast number of the most lucrative positions in connection with the civil engineering works of the country at large.

In connection with the, at times presented, subject of providing a civil corps for the execution of river and harbor works, which is presented in part at least on the claimed ground that such work is of a civil nature, I would say the Corps of Engineers is not taking any part in the question of what character of work shall be assigned to it by Congress, but is endeavoring to carry out to the best of its ability and earnestly such work as Congress in its judgment may call upon it to perform. It appears, however, to be the desire and intent of Congress that the execution of river and harbor and similar engineering work shall remain under the supervision of the Corps of Engineers, and therefore the Chief of Engineers feels it to be his duty, both in justice to the work and to his officers, to urgently ask that a sufficient number of officers be allowed the corps to properly do the work assigned to it.

And it may not in such connection be out of place to call attention to the fact that, as strongly presented by the Secretaries of War, it is necessary to have at the disposal of the Government for service in time of war a body of highly trained, experienced, and capable engineers, instructed both in their engineering and purely military duties, and it is important that this body of officers be trained during time of peace in duties allied to those they will be called upon to perform in time of war. It is only on the river and harbor and other engineering work of the General Government that such a body can be practically kept in training. Having such a body of men, it would seem wise that their services should be utilized in a manner which, while keeping them in training, will at the same time fully at all times reimburse the Government, through the value of services, the cost of maintenance, rather than confining such work in peace times to theoretical training and making them at such times a burden on the Treasury rather than a source of income.

The number of officers which would result from the proposed increase is imperatively needed for the proper execution of duties now devolving on the corps, and such number is understood to be still less than the number considered by the General Staff to be necessary at all times in connection with the construction of sea-coast defenses, military surveys, the improvement of the water communications, command of engineer troops, etc.

In connection with the military side of the engineering work of the Corps of Engineers, I may quote from a recent publication in a reference to the execution of public work by the corps: "What the digging of the Panama Canal needed was not only military engineering skill but military organization, military directness, military simplicity of purpose, military freedom from political contamination, and that fine esprit de corps of a military branch which makes the success or failure of one member of it the personal concern of the whole body; therefore we feel justified in pointing to the canal situation to-day and the inevitable completion of that waterway as a triumph of military preparedness."

Very sincerely,

WM. L. MARSHALL,
Chief of Engineers, U. S. Army.

Hon. J. A. T. HULL,

Chairman Committee on Military Affairs,

United States House of Representatives, Washington, D. C.

FORMULÆ FOR THE DESIGN OF GRAVITY RETAINING WALLS

BY

LIEUT. W. H. ROSE
*Corps of Engineers, United States
Army*

The following discussion is presented, not in order to add anything new to the already voluminous literature on this subject, but in the hope of presenting easily applied formulæ for the use of those engineers who prefer to base their design on formulæ derived from some one of the common theories of earth pressure rather than to obtain dimensions from purely empirical ones.

If A B C D (Fig. 1) represents the vertical section of a masonry retaining wall without surcharge, the following forces are considered as acting:

1. The weight of the wall, W . This is a vertical force and its point of application is the center of gravity of the section.
2. The weight, W' , of the triangular prism of earth, B D E. This is a vertical force, whose point of application is the center of gravity of the triangular section.
3. The force P , representing the lateral pressure due to the earth backing. This is assumed to be a horizontal force, acting against the vertical plane B E, whose point of application is one-third of the height of the wall above the base.

These are the assumptions on which the design of the lock walls of the Gatun locks at Panama were based. They are also used by Turneure and Maurer, "Principles of Reinforced Concrete Construction," edition 1909, page 372, and are believed to be fairly representative of modern engineering practice.

Some engineers consider also the force of the earth friction acting downward along the plane B E. (See letter by Mr. Chas. Worthington on "The Design of Retaining Walls," Engineering News, Volume LIV, November 16, 1905, pages 519-521.) The intensity

of this force is equal to $P \times$ the coefficient of the internal friction of the earth backing. It is neglected in the discussion which follows and, since the force adds to the stability of the wall, this neglect is on the side of safety.

The thrust due to the pressure of the earth backing can not be exactly determined either in direction, intensity, or point of application, and it is the uncertainty in the determination of this force which has led many engineers to discard all theories and rely simply on empirical formulæ based on experience and existing designs.

Many formulæ have been deduced by eminent engineers for

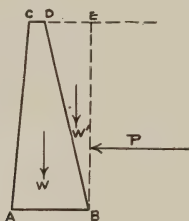


Fig. 1.

determining its intensity, and many theories proposed as to its direction and point of application.

Among the best known of the formulæ are those of Coulomb, Rankine, Weyrauch, and Poncelet. (See Baker, "Treatise on Masonry Construction," edition 1909, pages 493 and 494.)

Rankine's formula was used in the design of the Gatun lock walls and seems to be the one in most general use. For a wall without surcharge it is,

$$P = \frac{w' h^2}{2} \left(\frac{1 - \sin \varphi}{1 + \sin \varphi} \right)$$

where P = total horizontal pressure of earth backing in pounds.

h = height of wall in feet;

w' = weight of earth backing per cubic foot;

φ = angle of repose of earth — that is, angle between the natural slope and the horizontal.

Coulomb's formula is

$$P = \frac{w' h^2}{2} \tan^2 \left(45^\circ - \frac{\varphi}{2} \right)$$

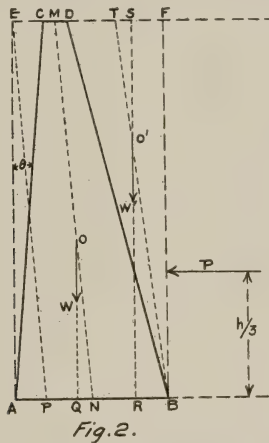
which is identical with Rankine's formula above, since

$$\tan \left(45^\circ - \frac{\varphi}{2} \right) = \sqrt{\frac{1 - \sin \varphi}{1 + \sin \varphi}}.$$

Baker gives the following experimental method of determining φ :

Thoroughly pulverize a mass of earth so as to destroy all cohesion between its particles; and then slowly pour it vertically upon a horizontal surface, thus forming a cone. The angle of the sides of this cone with the horizontal is φ , the angle of repose or the angle of natural slope.

Sometimes the earth pressure is taken as equivalent to the pres-



sure of a fluid having an assumed weight per cubic foot. In this case, if w'' represents the weight of the fluid per cubic foot,

$$P = \frac{1}{2} w'' h^2.$$

The following deductions are independent of the method of determining P, and the designer may select whatever formula he prefers.

Referring to Figure 1, the following conditions for stability should be fulfilled:

1. The resultant of the forces W, W', and P should not pierce the base outside the middle third—that is, there must be no tension at the heel, B.
2. The total unit pressure at A should not exceed the allowable unit pressure of the masonry in the wall or of the foundation.

The allowable unit pressure in the masonry is usually much greater than the pressure developed. If the unit pressure developed exceeds the allowable unit pressure on the foundation bed, a spread footing should be used to decrease the developed toe pressure or the allowable unit pressure should be increased by driving piles or otherwise.

3. To prevent sliding, the friction developed along the base AB due to the forces W and W' should be greater than the force P .

Assuming that the resultant pressure due to the weight of the wall W , the weight of the earth W' , and the pressure P , intersects the base at the edge of the middle third nearest A, according to the first condition above, the moment of the resultant about this point must be zero. That is, the sums of the moments of its components must be zero. Or

$$Pl'' = Wl + W'l'$$

where l , l' and l'' are the lever arms of the forces W , W' and P , respectively, about the edge of the middle third nearest the toe of the wall.

Referring to Figure 2, the lever arm of P is $\frac{h}{3}$, since the point of application of P was assumed to be one-third of the height of the wall above the base.

Hence $l'' = \frac{h}{3}$, and moment of force P about edge of middle third is $\frac{Ph}{3}$.

To find l and l' , refer to Fig. 2.

Let $a = CD =$ width top of wall.

$b = AB =$ width base of wall.

$h = EA =$ height of wall.

$\theta =$ angle $EAC =$ angle of batter front face.

O be center of gravity of trapezoid $ABCD$.

O' be center of gravity of triangle BDF .

OQ and SR be perpendicular to AB .

MN be line joining middle points of AB and CD .

BT be line joining B with middle point of DF .

EP be parallel to MN .

The centers of gravity, O and O', lie on MN and BT, respectively.

$$l = \frac{b}{6} - QN.$$

$$QN = \sqrt{ON^2 - OQ^2}$$

$$\text{but } ON = \frac{MN}{3} \times \frac{2a+b}{a+b} \text{ and } OQ = \frac{h}{3} \times \frac{2a+b}{a+b} \text{ (Trautwine),}$$

$$\text{and } MN = EP = \sqrt{h^2 + AP^2}. \text{ But } AP = \frac{b}{2} - PN = \frac{b}{2} - EM = \frac{b}{2} - \frac{a}{2}$$

$$-h \tan \theta, \text{ whence } l = \frac{b}{6} - \left[\frac{2a+b}{3(a+b)} \right] \left[\frac{b}{2} - \frac{a}{2} - h \tan \theta \right].$$

If w = weight of masonry per cubic foot, then for a section of wall one foot long

$$W = \frac{wh(a+b)}{2}$$

and moment of force W about edge of middle third is

$$Wl = \frac{wh(a+b)}{2} \left\{ \frac{b}{6} - \left[\frac{2a+b}{3(a+b)} \right] \left[\frac{b}{2} - \frac{a}{2} - h \tan \theta \right] \right\}$$

Also,

$$l' = \frac{2b}{3} - RB.$$

$$RB = SF = \frac{2}{3} \frac{TF}{3} = \frac{DF}{3},$$

but $DF = b - ED = b - a - h \tan \theta$,

whence

$$l' = \frac{2b}{3} - \frac{b-a-h \tan \theta}{3} = \frac{b+a+h \tan \theta}{3}.$$

If w' = weight of earth backing per cubic foot, then for a section of wall one foot long

$$W' = \frac{w' \times DF \times h}{2} = \frac{w'h(b-a-h \tan \theta)}{2}$$

and moment of force W' about edge of middle third is

$$W'l' = \frac{w'h}{6} (b+a+h \tan \theta) (b-a-h \tan \theta).$$

Substituting in the moment equation, $Pl'' = Wl + W'l'$, the values of l'' , Wl , and $W'l'$ found above, we have

$$\frac{Ph}{3} = \frac{wh(a+b)}{2} \left\{ \frac{b}{6} - \left[\frac{(2a+b)}{3(a+b)} \right] \left[\frac{b}{2} - \frac{a}{2} - h \tan \theta \right] \right\} \\ + \frac{w'h}{6} (b+a+h \tan \theta) (b-a-h \tan \theta),$$

from which

$$P = \frac{w}{2} (a^2 + 2ah \tan \theta + bh \tan \theta) + \frac{w'}{2} (b^2 - a^2 - 2ah \tan \theta - h^2 \tan^2 \theta)$$

whence

$$b = -\frac{wh \tan \theta}{2w'} \\ + \sqrt{\frac{2P - a^2(w-w')}{w'} - \frac{2ah(w-w') \tan \theta}{w'} + \frac{w^2 h^2 \tan^2 \theta}{4w'^2} + h^2 \tan^2 \theta} \quad (A)$$

This is the general equation of the retaining wall without surcharge, under the assumptions made.

If the front face is vertical, as in the ordinary lock wall, $\tan \theta = 0$ and

$$b = \sqrt{\frac{2P - a^2(w-w')}{w'}} \quad (B)$$

From equations (A) or (B) if P , w , w' , a , h and θ are known, the thickness of the base, b , of the wall can be found and with this value of b , under the assumptions made, the resultant of the forces will pierce the base at the forward edge of the middle third. This fulfills the first condition of stability.

The maximum pressure on the toe of the wall at A is given by the equation

$$P_1 = \frac{W + W'}{b} + \frac{6(W + W')d}{b^2}.$$

(See Baker, p. 472, Equation 19)

where P_1 = maximum pressure per square foot at A,

d = distance of center of pressure from center of base in feet.

W and W' = weights of masonry and earth, as before, for one foot length of wall.

b = length of base in feet.

When the center of pressure is at the edge of the middle third nearest A,

$$d = \frac{b}{6} \text{ and } P_1 = \frac{2(W + W')}{b}$$

From this equation we can determine whether or not the second condition for stability is fulfilled.

The force of the friction along the base AB is equal to $F = (W + W')f$ where f is the coefficient of friction of the masonry on the material upon which it rests. If $f(W + W')$ is greater than P the wall is safe against sliding and the third condition of stability

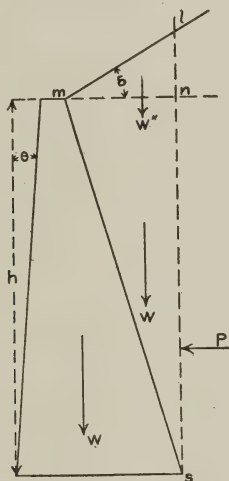


Fig. 3.

is fulfilled. For the type of wall under discussion the friction developed is usually ample to insure stability against sliding.

SURCHARGED WALLS

For a wall carrying a surcharge at an angle δ with the horizontal, Rankine's formula for the horizontal earth pressure is

$$P = \frac{\frac{1}{2}w'h^2 \cos^2 \varphi}{\cos \delta \left(1 + \sqrt{\frac{\sin(\varphi + \delta) \sin(\varphi - \delta)}{\cos \delta}} \right)^2} \quad (c)$$

and if $\delta = \varphi$, the angle of repose, the assumption usually made,

$$P = \frac{1}{2}w'h^2 \cos \varphi \quad (d)$$

The resisting moment is increased by the moment of the weight of the small triangular prism $l m n$, see Fig. 3. For unit length of wall this weight is

$$W'' = \frac{w'}{2} (b - a - h \tan \theta)^2 \tan \delta.$$

Its lever arm about the forward edge of the middle third is the same as that of the prism $m n s$, viz:

$$\frac{b + a + h \tan \theta}{3}.$$

Its moment is

$$\frac{w' \tan \delta}{6} (b - a - h \tan \theta)^2 (b + a + h \tan \theta).$$

The moment equation then is,

$$\begin{aligned} \frac{P h}{3} &= \frac{w h (a + b)}{2} \left\{ \frac{b}{6} - \left[\frac{2}{3} \frac{a + b}{(a + b)} \right] \left[\frac{b}{2} - \frac{a}{2} - h \tan \theta \right] \right\} + \frac{w' h}{6} (b + a + h \tan \theta) (b - a - h \tan \theta) \\ &+ \frac{w' \tan \delta}{6} (b - a - h \tan \theta)^2 (b + a + h \tan \theta) \text{ or} \\ P &= \frac{w}{2} (a^2 + 2 a h \tan \theta + b h \tan \theta) + \frac{w'}{2} (b^2 - a^2 - 2 a h \tan \theta - h^2 \tan^2 \theta) \\ &+ \frac{w' \tan \delta}{2 h} (b - a - h \tan \theta) (b + a + h \tan \theta) \quad (E) \end{aligned}$$

This is the general equation for the surcharged retaining wall under the assumptions made.

If the front face is vertical, $\tan \theta = 0$ and

$$P = \frac{w a^2}{2} + \frac{w' (b^2 - a^2)}{2} + \frac{w' \tan \delta}{2 h} (b - a)^2 (b + a) \quad (F)$$

It will be noted that equations (E) and (F) are cubics, considering b as the unknown quantity. They may be readily solved by successive approximations, substituting for b , in the last term of the second member, approximate values. For the first approximation, for the type of walls shown in the figures, b may be taken as $.47h$ for the wall with battered face and $.49h$ for the wall with vertical face. See examples 3 and 4.

The unit pressure at the toe will be

$$\frac{2(W + W' + W'')}{b}.$$

The force resisting sliding will be $f(W + W' + W'')$.

Example No. 1: No surcharge. Face batter $\frac{1}{12}$.

Assume $h=32$ =height of wall in feet.

$a=2$ =width of top in feet.

$w=140$ =weight of masonry per cubic foot.

$w'=100$ =weight of earth backing per cubic foot.

$\varphi=41^\circ 49'$ $\sin \varphi=\frac{2}{3}$ =angle of repose of earth.

$\tan \theta=\frac{1}{12}$ =batter of front face.

From Rankine's formula,

$$P=\frac{w'h^2}{2}\left(\frac{1-\sin \varphi}{1+\sin \varphi}\right)$$

$P=10,240$ pounds.

$b=12.6$ feet=width of base. $\left(\frac{b}{h}=.394\right)$

$$P_1=\frac{2(W+W')}{b}=\frac{2(32,700+12,680)}{12.6}=7,200 \text{ lbs. per square foot.}$$

This is a very low value so far as the allowable stresses in the masonry are concerned. It would be within the limits of safety for almost all soils excepting soft clay or quicksand.

Friction on base= $f(W+W')$.

Assume base of wall rests directly upon a dry sand bed and that the coefficient of friction of masonry on sand is .45.

Then $F=20,420$ lbs., which is practically twice the intensity of P , the force tending to produce sliding.

Example No. 2: No surcharge. Vertical face.

If the same values of h , a , w , w' and φ be taken, but the condition be imposed that the wall shall have a vertical face, we have,

$P=10,240$ pounds.

$b=14.25$ feet. $\left(\frac{b}{h}=.445\right)$

$P_1=7,900$ pounds per square foot.

$F=25,200$ pounds.

It will be noted that the base must be considerably wider in the second case than in the first. In the wall with a face batter of 12 on 1 the weight per foot length is 32,700 pounds, while for the vertical face wall the weight per foot length is 36,400 pounds, showing that a considerable saving can be effected by using the battered type.

Example No. 3: Wall surcharged at angle of repose. Face batter $\frac{1}{12}$.

Assume $h=32$.

$a=2$.

$w=140$.

$w'=100$.

$\varphi=\delta=41^\circ 49'$.

$\tan \theta=\frac{1}{12}$.

Then from equation (D), $P=\frac{1}{2} w'h^2 \cos \varphi=17,060$ lbs.

From equation (E), (substituting $.47h=15$ feet for b in the last term of the second member).

$b=15.1$ feet. $\left(\frac{b}{h}=.472\right)$

$W=32,700$.

$W'=12,680$.

$W''=4,780$.

P_1 =pressure at toe=6,680 lbs. per square foot.

If $f=.45$.

$F=22,600$ lbs.

Example No. 4: Wall surcharged at angle of repose. Vertical face. Same assumptions as above but vertical face.

$P=17,060$ lbs.

$b=15.7$ feet. $\left(\frac{b}{h}=.491\right)$

$W=39,650$ lbs.

$W'=21,920$ lbs.

$W''=6,140$ lbs.

$P_1=8,640$ lbs. per square foot.

$F=30,470$ lbs.

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Compiled by Henry E. Haferkorn, Librarian, Engineer School

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- (2) American Machinist; weekly; Thursdays.
- (3) Canadian Engineer; monthly.
- (4) Canadian Society of Engineers, Bulletins; May and December each year. Proceedings; monthly.
- (5) Cassier's Magazine; monthly.
- (6) Cement; bi-monthly.
- (7) Cement Age; monthly.
- (8) Cornell Civil Engineer; monthly.
- (9) Electrical Review; weekly; London.
- (10) Engineer (London); weekly.
- (11) Engineering (London); weekly.
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- (14) Engineering News; weekly; Thursdays.
- (15) Engineering Record; weekly; Saturdays.
- (16) De Ingenieur (Hague, Holland); weekly.
- (17) Journal of American Society of Mechanical Engineers.
- (18) Journal of Western Society of Engineers; bi-monthly.
- (19) Journal of Franklin Institute; monthly.
- (20) Journal of Royal United Service Institution (London); monthly.
- (21) Proceedings, American Society of Civil Engineers; monthly.
- (22) Proceedings, Engineer's Club of Philadelphia; monthly.
- (23) Municipal Engineer; monthly.
- (24) Municipal Journal and Engineer; monthly.
- (25) Railway Age and Gazette; weekly; Fridays.
- (26) Revue Générale des Chemins de Fer (Paris); monthly.
- (27) Scientific American; weekly; Saturdays.
- (28) Scientific American Supplement; weekly; Saturdays.
- (29) Transactions, American Society of Civil Engineers.
- (30) Professional Memoirs, Corps of Engineers; quarterly.
- (31) Journal of the Royal Artillery (Woolwich, Eng.); monthly.
- (32) Royal Engineers' Journal (Chatham, Eng.); monthly.

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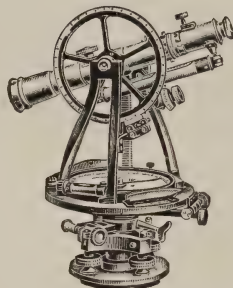
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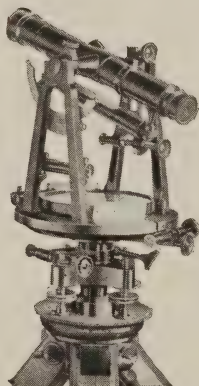


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Editorial Notes

The work with the experimental, portable, field searchlight outfits, which will form a part of the equipment of the companies of the First Battalion of Engineers at the maneuvers this summer, should prove to be a very interesting feature to both the regular and militia organizations present.

No extensive experiments in the field with portable searchlight and generating apparatus have as yet been made in this country, although a number of European nations have been working along these lines for several years.

The apparatus to be taken to the maneuvers this year comprises two 30-inch and one 24-inch projector and two generating plants. One of these is the "Auto-Searchlight Car," a self-propelled gasoline engine driven generating set of 15-kilowatt capacity. The other is the new experimental set, which has just been completed for the Field Artillery, a gasoline-engine generating set of 7-kilowatt capacity, mounted on a four-wheel truck for animal traction. The auto-searchlight car is accompanied by a 30-inch light of latest design, mounted on a two-wheel trailer and controlled by one of the new General Electric controllers; also by a 24-inch light, mounted with a telescoping tower on a four-wheel truck. This light is being arranged for interchangeable control by either a Le Blanc controller or a six-wire controller of the type described in Artillery Notes, No. 31. The Field Artillery generating set is accompanied by a 30-inch light, with new General Electric controller, mounted on a four-wheel truck.

The auto-searchlight car is of novel and interesting design and, together with the other apparatus mentioned above, will be described in coming numbers of the MEMOIRS.

The experience in the South African War and in the war between Russia and Japan has made very material changes in the entire subject of Field Fortification. The introduction of the small arm with a very flat trajectory, and, more especially, the general acceptance of indirect laying as the proper method of using field artillery, have been the two factors which have brought about the greatest change in the previously accepted methods of Field Fortification. These changes practically all hinge on the question of visibility, and the leading military nations of the world have, within the past few years, revised the entire subject of Field Fortification as laid down in their service manuals on that subject. The reprint appearing in this number of the PROFESSIONAL MEMOIRS is a very

timely and a very good discussion of this subject, being a comparison of the German regulations for Field Fortification with a Russian book, which gives a very complete analysis of the experience in Manchuria in regard to Field Fortifications. In reading this article, it must, of course, be kept in mind that the subject of permanent land defense is not dealt with and that the points brought out have to deal with the subject of hasty fortifications constructed in the field, or with those of a somewhat more permanent nature, likewise constructed in the field, but under conditions where more time is available and more permanent works, though still of a temporary character, can be constructed. It will be noticed that the article has little to say in regard to the subject of redoubts. In fact, the word "redoubt" itself has come to be a term that is used more and more sparingly in connection with Field Fortifications, because of the meaning that involuntarily attaches to this word through its commonly accepted use in past times in connection with permanent fortifications. The name "supporting point" or "ring trench" is a term that is coming into use to describe a point in line of Field Fortifications at which a temporary defense can be made after a part of the main line of trenches has been broken. There is no belief or expectation that these supporting points can hold out for more than a few hours after the main trench line has been broken, unless reserves come to their assistance; they will probably be captured within, say, twelve hours; but, in the meantime, they offer a series of points in the line which can not be carried by a rush and from which the troops can not be driven by an attack parallel with, and in rear of, the line of trenches.

It is hoped that we can give in the next number of the MEMOIRS an article upon the subject of Supporting Points, with drawings and plans, and another article is in contemplation, showing the experience of this class of works in the Russo-Japanese War.

We feel that interest in the MEMOIRS would be strengthened and its value as a means of interchange of information as to new ideas and methods of work increased if our readers would favor us with brief news items and comments and criticisms of published articles. While papers giving detailed description of works in progress or completed are, of course, greatly desired, we would be glad at all times to receive short notes and memoranda that will not require the time and labor involved in the preparation of a long paper, but will still be of much value and interest.

In time we hope to be able to send out advance copies of articles for comments and discussion to be published in the same number of the MEMOIRS, but this has not as yet been practicable.

PROFESSIONAL MEMOIRS

Corps of Engineers, United States Army, and Engineer Department at Large

Published Quarterly at the Engineer School, Washington Barracks, D. C., by the School Board. NOTE: Authors alone are responsible for statements made and opinions expressed in their respective articles.

VOL. II.

OCTOBER-DECEMBER, 1910.

No. 8.

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Subscriptions, \$3.00 per year, in advance; single copies, 75 cents. Advertising rates on application. Address all communications to PROFESSIONAL MEMOIRS, Washington Barracks, D. C.



MAJ. GEN. ALEXANDER MACOMB

CHIEF ENGINEER, UNITED STATES ARMY

1821-1828

GENERAL IN CHIEF, UNITED STATES ARMY

1828-1841

BORN 1782—DIED 1841

THE BALTIMORE LIGHT-HOUSE

BY

LIEUT. COL. W. E. CRAIGHILL
Corps of Engineers

In 1890, Captain John C. Mallery, United States Light-House Engineer, asked for \$60,000 to construct the Baltimore light-house, and the Light-House Board recommended that the amount be appropriated by Congress. The Board recommended the same amount each succeeding year until 1894, when Congress appropriated the money.

In 1895, borings were made at a site selected and several projects were considered and rejected. In 1896, plans and specifications for a structure were under consideration, but owing to contemplated improvements in the harbor by which the channel might be changed, the location of the light was not determined.

In 1897, a new site was selected in 23 feet of water to the westward of the southerly entrance to Craighill Channel, Md., entrance to Baltimore Harbor, westerly side of the northerly end of Chesapeake Bay, and $2\frac{5}{8}$ miles N. $\frac{3}{4}$ W. from Sandy Point Light-house in latitude $39^{\circ} 03' (36'')$ and longitude $76^{\circ} 23' (52'')$. A test pile was driven, and projects for a structure were prepared.

In 1898, an experimental disk pile to be placed at or near the site of this light-house was constructed, and on September 9 an unsuccessful effort was made to plant it at the site. After two hours' continuous pumping with two pumps, having 4-inch suction with 3-inch and 2-inch discharges, respectively, the pile could be made to sink only 3 feet 6 inches into the mud stratum. Further attempt was accordingly abandoned, and the pile was brought back to Baltimore. It was then evident that the expense of building a light-house in the 55 feet of semifluid mud which overlies the sandy bottom would be great. It was estimated that, to build this light-house at the site finally selected, it would cost \$60,000 in addition to the \$60,000 already appropriated.

In 1899, the Board recommended to Congress the appropriation of an additional \$60,000.

In 1900, the Board again recommended the appropriation of the additional \$60,000, or that authority be given to contract for the work at a cost not exceeding \$120,000.

In 1901, the Board made the same recommendations as in 1900.

In 1902, the additional \$60,000 was appropriated, making a total of \$120,000 available for building the light-house. A design for the proposed structure was approved on October 13, 1902, and the preparation of detail drawings and specifications commenced at once, and on April 6, 1903, they were approved.

On June 4, 1903, separate proposals were opened for the metal work and erection of the light-house, and were as follows:

METAL WORK

Richmond Iron Works, Richmond, Va.....	\$31,247.00
The Allentown Rolling Mills, Allentown, Pa.....	34,875.00
Atlanta Machine Works, Atlanta, Ga.....	28,522.50
Russell Wheel & Foundry Co., Detroit, Mich.....	30,740.00
Ellicott Machine Co., Baltimore, Md.....	31,984.00
New Jersey Foundry & Machine Co., Plainfield, N. J.....	42,500.00

ERECTION

The Foundation & Contracting Co., New York, N. Y.....	198,760.00
---	------------

As the proposal for the erection was excessive and nearly \$80,000 more than the amount available for completing the entire structure, it was rejected and action on the proposals for the metal work was suspended until it could be ascertained by readvertising whether a satisfactory offer could be obtained for the erection of the light-house.

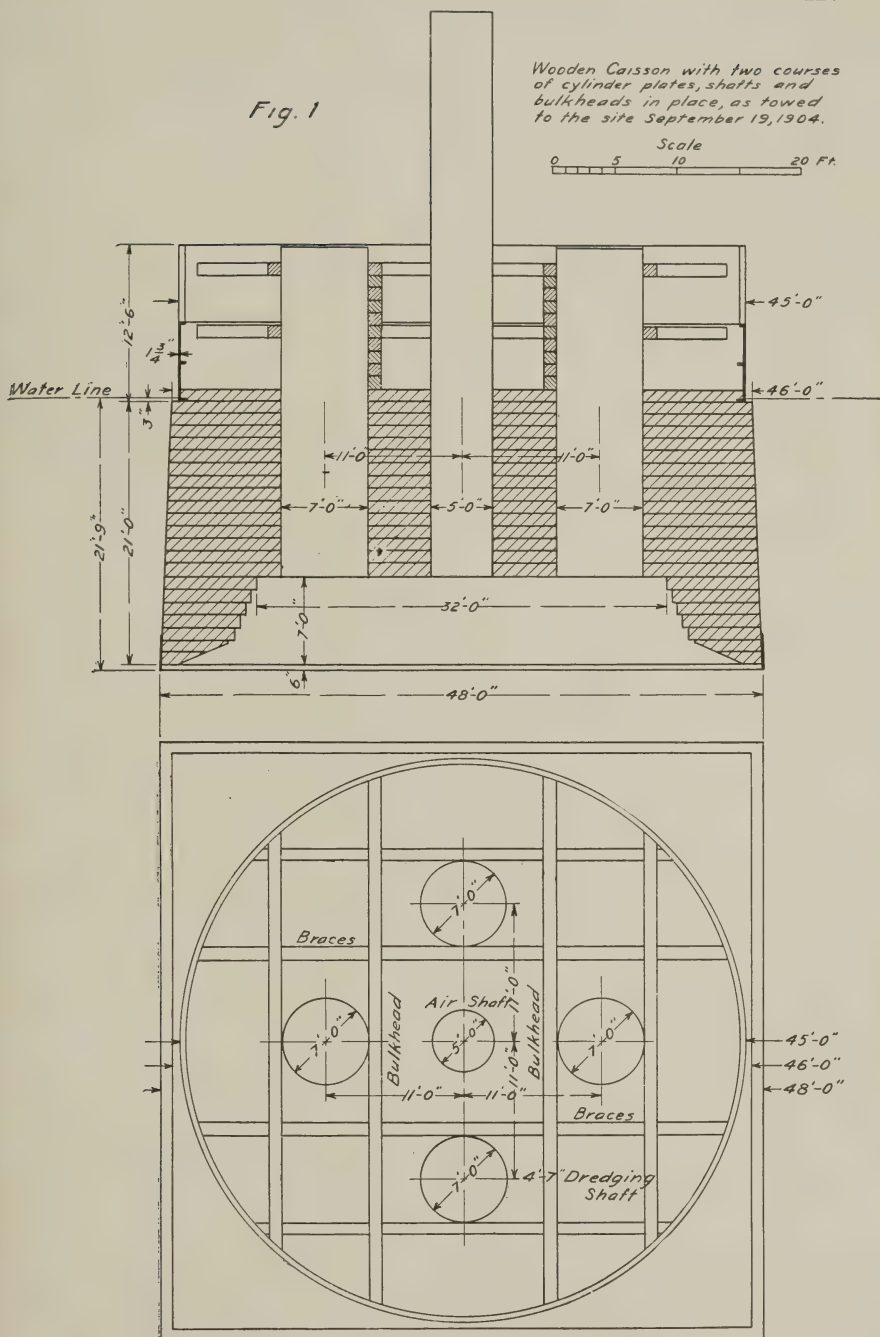
The work of erecting the light-house was readvertised and proposals for same were opened September 3, 1903, as follows:

The Foundation & Contracting Co., New York, N. Y.....	\$188,760.00
Wm. H. Flaherty, New York, N. Y.....	91,900.00

As the lowest proposals received for the metal work and erection exceeded the appropriation, modifications were made in the plans and specifications for the erection. The Atlanta Machine Works, on account of a reduction in the price of iron, reduced their bid to \$27,972.50, and Wm. H. Flaherty, in consideration of the modifications in plans and specifications for erection, reduced his bid to \$86,000.00, making a total of \$113,972.50, leaving \$6,027.50 for lens, fog signal, superintendence, etc.

Fig. 1

Wooden Caisson with two courses of cylinder plates, shafts and bulkheads in place, as towed to the site September 19, 1904.



On January 8, 1904, a contract was made with the Atlanta Machine Works for the metal work for \$27,972.50. By June 30, the first six courses of cylinder plates were delivered at the light-house depot, Lazaretto Point, Baltimore, Md., and on September 9, 1904, the balance were delivered.

On December 10, 1903, a contract was made with William H. Flaherty for the erection for \$86,000. On May 9, 1904, the first course of timber was laid for the caisson on the shore at Lazaretto Point, and by the end of June the caisson was ready for launching, twelve courses of timber were in place, and the five steel working shafts were set up. The launching ways were then completed, and, after several attempts, the caisson was launched August 9, 1904. The balance of the timber was then added to the caisson, two courses of cylinder plates were set up, and the bulkheads were built up in place.

The caisson in this condition, with the 6-inch steel cutting edge, drew 21 feet 9 inches of water, and the top of the last course of timber deck inside of cylinder plates was 9 inches above water. A heavy rain fell on September 15, and in a few hours had leaked out of the cylinder, showing the woodwork was not water-tight. All joints in the woodwork of the top course that could be reached were then calked.

The contractor loaded cement, sand, gravel, and large stone on his three barges in Baltimore, and about 3 p. m., September 18, 1904, with barges and caisson in tow of three tugs, started for the site, arriving at noon next day, September 19.

Concrete and stone was placed in east and west compartments of the cylinder, and, at 11 p. m., the caisson was grounded in position. The work of filling the east and west compartments of the cylinder was continued, and, on the morning of the 20th, the caisson had a list to westward of about 3 feet, with about 2 feet 4 inches of concrete in the west compartment and 1 foot in the east compartment. The water that had leaked into cylinder during the night was partly pumped out, and work was resumed in the east compartment and continued during the 20th and until 10 p. m. of the 21st, when the concrete averaged 4 feet 6 inches in the east compartment and remained 2 feet 4 inches in the west compartment. After 10 p. m., it got quite rough and the seas broke over top of the cylinder and filled it, and it settled to eastward; the top of the second course cylinder plates on the east side going 2 feet below the water and the west side remaining 5 feet out, making the cylinder 7 feet out of

level, with the caisson about 8 feet in the soft mud on an average. During the night a large lug on the side of the cylinder cut a hole in the side of the barge which provided living quarters for most of the men engaged on the work, some 85 or 90, and by 6 a. m., September 22, the barge had about 7 feet of water in the hold and was filling at the rate of about 1 foot per hour. The lines were taken in, the anchor chain slipped, and with a northeast wind the barge started to drift ashore. The contractor's tug, which had been in the harbor, came out at 8.30 a. m. and beached the barge, which had 10 feet of water in the hold and could not have stayed up more

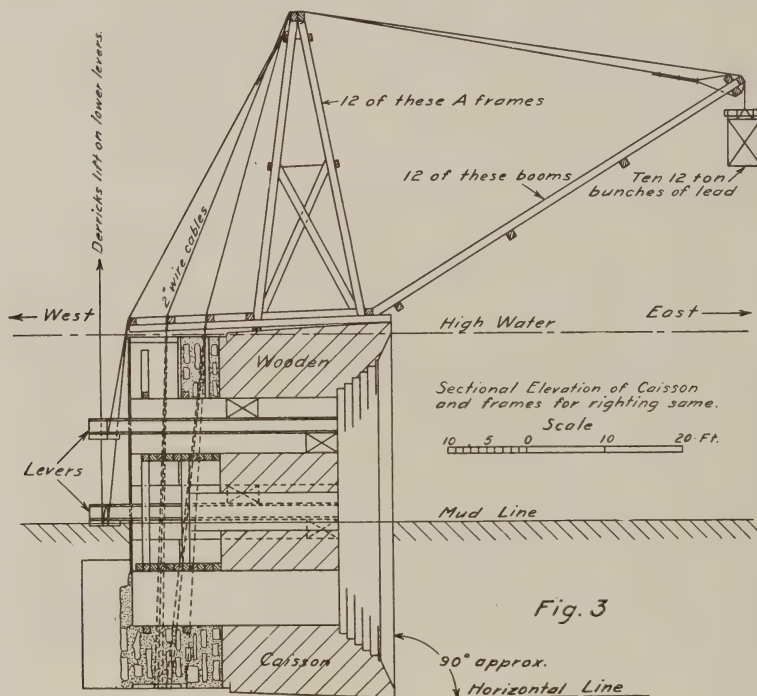


Fig. 2. Setting third course of cylinder plates, September 24, 1904.

than a couple of hours longer. Temporary repairs were made to the barge by a diver during the day; the water was pumped out by the tug that night, and the next morning, September 23, the barge was towed back to the site.

On the 23d and 24th, the third course of cylinder plates was set and the anchor, which had been slipped, was picked up. On September 26, part of the water was pumped out of the cylinder and concreting was started in the west compartment and continued until 4 a. m. of the 27th, when the pump gave out and the water raised over the concrete, which averaged 1 foot 6 inches above top of first course cylinder plates. During the balance of the day, September 27, the fourth course cylinder plates were set. On the

28th, the barges were towed back to Baltimore for repairs and material, and on October 7 left Baltimore and arrived at the site. On October 8, the water was pumped out of the cylinder and concrete was placed in the west compartment until, on the 10th, it stood one course of stone above the top of the bulkhead, or about 11 feet high in the west compartment, when contractor was told he could go no higher until he raised the concrete in east and center compartments.



The matter was taken up with the Light-House Engineer in Baltimore. The contractor claimed that the only way he could right the caisson was to load the west side; and, as he agreed to take all responsibility, he was allowed to place more concrete over the west compartment. The work was then continued until 12.30 a. m., October 12, when the concrete averaged 3 feet above top of bulkhead. The wind blew so strong during the night that the barges were pulled clear of cylinder, and at daylight it was blowing a gale. At 6.30 a. m., the caisson had righted and begun to list to the westward, and by 2.30 p. m. the caisson and cylinder was lying on its side, showing about 3 feet 6 inches above water. During the

storm one of the barges broke loose, went ashore, and filled with water, ruining about 1,000 bags of cement. The barge was pumped out and taken off the beach later.

The barges were towed to Baltimore, and the contractor abandoned work on the light-house and went into the hands of a receiver, who took charge of his plant October 19, 1904.

The receiver had a light kept on the caisson until June 19, 1905,

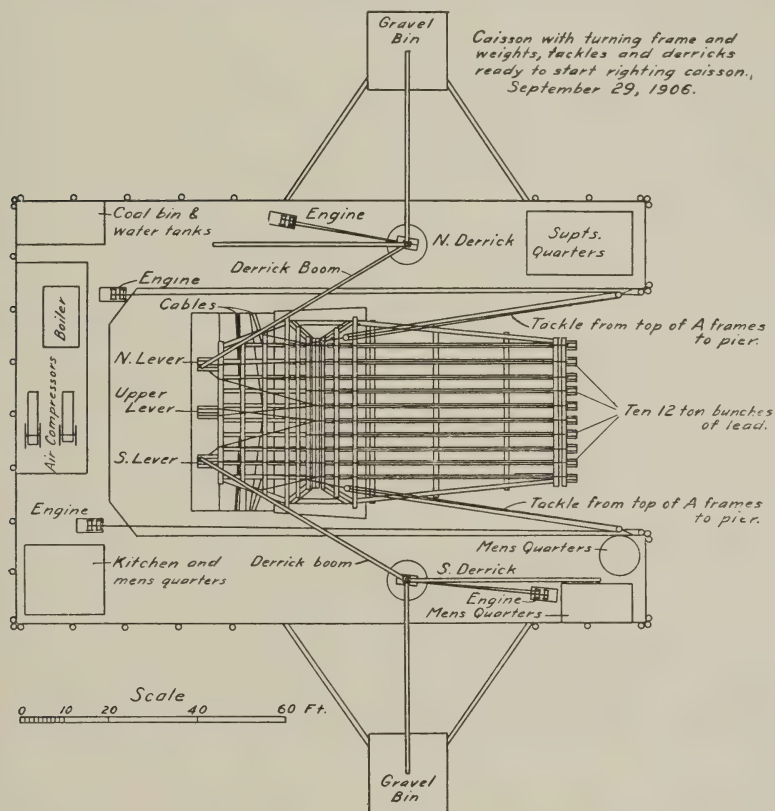


Fig. 4.

when he turned the contractor's plant over to the bonding company, the United States Fidelity and Guaranty Company, for the completion of the work.

On August 16, 1905, the bonding company made a contract with John D. Miller, of New York, to complete the work, and on August 31st one of the barges, with a diver and 6 or 7 men, was towed to the site. A boom was rigged up on the barge, and on September 6

the work of recovering the cylinder plates was started and continued off and on until near the middle of December, when the work was stopped. Fifty-five good and 7 cracked cylinder plates and one 20-foot section of air shaft were taken up. From the time the caisson capsized, October 12, 1903, until the work started, September 6, 1905, the caisson had settled about 2 feet deeper into the mud.

On May 18, 1906, Wm. H. Flaherty was notified of the annulment of his contract, and on March 14, 1907, a contract was made with the United States Fidelity and Guaranty Company, as principal, to complete the light-house on or before November 30, 1907.

In April, 1906, the work of building a temporary pile pier to hold the machinery, men's quarters, etc., was started by the bonding company, and on June 15 it was completed.

A 6-inch pipe well was sunk 186 feet 4 inches below high water for fresh water and a flow of 5 gallons per minute was received, which filled the requirements during the entire time that the work was in progress.

The machinery and derricks to be used in righting the caisson and quarters for the men were placed on the pier.

All of the second course cylinder plates that had been removed were replaced. Sills were placed on top of the wooden caisson and timbers were bolted across them west of the "A" frames to spread the cables. "A" frames were placed on the sills, and timbers forming a saddle or ridge were placed on top of the "A" frames. Timbers forming a boom were set in place, their lower ends resting against the bottom of the "A" frames and their upper or outer ends suspended from the saddle of the "A" frames on the side opposite the cylinder. Cables were passed under the cylinder and the ends were taken through the spreaders, over the saddle of "A" frames and out over end of boom, and to each was attached a bunch of pig lead weighing 12 tons. There were 10 bunches, or 120 tons all told, hung from the end of the boom. Other cables were passed under the cylinder and the ends were made fast to the saddle of the "A" frames and to the end of the boom to insure their remaining in position. Three levers, each composed of four 2-foot I-beams, packed out with timbers, were made and placed in the north, south, and east dredging shafts. Cables were passed around the outer ends of the levers and fastened to the saddle of the "A" frames. Cables from the ends of the levers in the north and south shafts were also taken to the two

derricks on the pier, each of which had a lifting capacity of about 15 tons. The mud was pumped away from the caisson on the north, east, and south sides, and 38 clamps were placed from the cutting edge to the top of third course cylinder plates to hold the caisson and cylinder together while righting. A tackle of about 6 tons' capacity was rigged from each end of the saddle of the "A" frames to the piles at the east end of the pier, and the hauling parts were led to an engine on the pier. On September 27, a

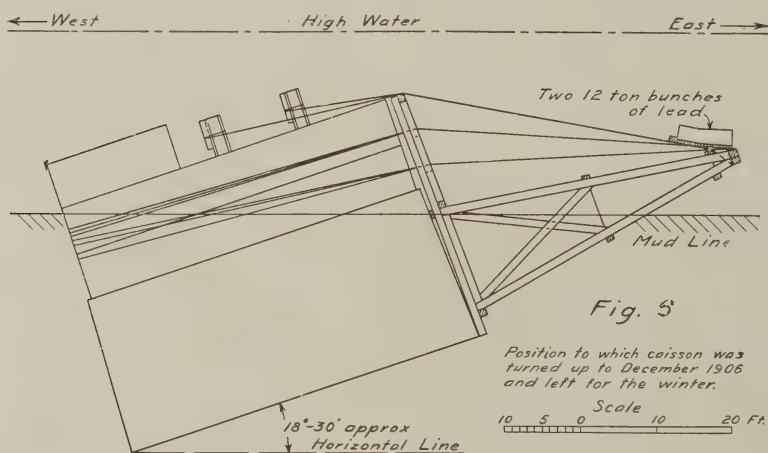


Fig. 5. Turning frame and derricks lifting on levers, September 28, 1906.

strain was taken on the tackles and derricks and the top of the caisson moved to eastward about 5 inches. A strain was kept on the caisson all that night and most of the next day, during which time an additional movement of 3 feet 11 inches was noted, making 4 feet 4 inches all told. At noon on the 29th, a heavy pull was made with the engines, and the caisson made a start and did not stop until it had turned to within 47 degrees of its horizontal, or proper, position, and the lead weights were buried in, and the ends of the booms rested on, the mud at the bottom of the bay. The

tackles from the ends of the saddle to the east end of the pier were lowered on the east ends to the mud line on the piles, and a strain was taken on them. The 120 tons of lead were taken up and 72 tons placed on the outer ends of the "A" frames. The booms, being released, floated up and were taken away. Mud was then pumped from under the "A" frames and the high side of the caisson, and when work was stopped for the winter the caisson was about 80 per cent righted, or to within 18 degrees of level. Forty-eight tons of lead were taken off the ends of the "A" frames, leaving 24 tons on them for the winter.

The plant was removed from the pier December 19, 1906.



During the winter the ice carried away the small pier on the north side of the main pier.

In April, 1907, the machinery was replaced on the pier and work started again. Tackles were rigged from the cylinder to the east end of the pier. The 24 tons of lead remaining on the "A" frames were removed, and the "A" frames and levers were taken from the caisson. Mud was pumped from under the high side of the caisson, and with a load of about 180 tons of large stone, which was placed in the center and east compartments in the cylinder, and the cylinder plates, which were set up to the sixth course, inclusive, on the caisson, it settled to within 7 degrees of level. As the pneumatic process for sinking the caisson was much safer than to dredge through the four outer shafts, it was decided to close the shafts up. Doors were hung at the bottoms of the shafts and concrete was placed in each to a height of about 8 feet. Twelve-

inch pipes for passing the concrete into the working chamber were set in north and south shafts and used to good advantage when the caisson was to full depth and ready to fill. The seventh course of cylinder plates was set, and about 160 tons of large stone and 655 cubic yards of sand were added to the load on the caisson. Shores were placed on top of the caisson and under timbers bolted to piles of pier to hold the caisson down while pumping out the cylinder. An old canvas cover was placed around the cylinder and an unsuccessful attempt was made to pump it out. A new canvas cover was then made and placed around the cylinder, six scow loads of mud



Fig. 7. Baltimore light, practically complete; showing pier used in construction.

were dumped around the bottom of it, and the cylinder was pumped out.

The ballast in the cylinder was shifted as the concrete was raised until there was enough concrete in place to hold the caisson down, after which the concrete was placed regularly until October 2, 1907, when it was 5 feet 3 inches above top of sixth course cylinder plates. On October 5 the air pressure was put on the caisson and taken off November 28, during which time the caisson had been sunk to depth (82 feet below high water), and the working chamber was filled with concrete. The eighth, ninth, tenth, and eleventh courses of cylinder plates were set, the air shaft was lengthened, and the con-

crete was raised to 5 feet 6 inches above top of ninth course cylinder plates. The air locks and pipes were then removed from the caisson, the twelfth and thirteenth courses of cylinder plates were set, and the concrete, with the cistern forms and connecting pipes embedded in it, was raised to 4 feet above top of eleventh course cylinder plates. A lot of the iron work which was on hand for the house was placed on the concrete, a temporary wooden cover was placed over the top of the cylinder, and in this condition the structure was left for the winter. On December 16, 1907, the last of the machinery, derricks, etc., was removed from the pier and taken to Baltimore.

The pier sustained no material damage during the winter, and in April, 1908, part of the plant was returned to the pier and the work was again started on the light-house. On August 13, 1908, the plant was taken off the pier, which was then removed.

On September 8, 1908, the light-house was completed and ready for occupancy.

The greatest number of men engaged at one time on this work was while sinking the caisson in November, 1907, when 124 men were employed.

The following was given by the United States Fidelity and Guaranty Company from their books:

Total cost of building the light-house and settling claims against Wm. H. Flaherty (the original contractor)	\$180,359.71
Amount received from United States Government for the work, and from sale of plant.....	\$86,357.63
Estimated value of plant on hand.....	3,000.00
	89,357.63
Net loss	\$91,002.08

REDOUBTS AND FIELD FORTIFICATIONS

BY

MAJ. WM. D. CONNOR

Corps of Engineers

It has long been recognized that any line of permanent or semi-permanent land defense must have certain points made stronger than the general line of trenches, in order that the effect of the capture of a part of the line may be localized and that a break at one point in the line does not mean that the rest of the line can be rolled up from the flank. These points were called redoubts, and have usually been placed at points of natural strength and, when practicable, within supporting distance of one another.

The term redoubt, thus used through several centuries, has come to represent to most minds a certain fixed type of work whose characteristics and essential points have become standard in all military writings.

That suitable reasons for the creation of such points in the line of defense still exist is doubted by some, who maintain that troops in a line of trenches with a field of fire of over 500 yards are safe against the attack of from four to five times their number.

This view is the extreme one; the more moderate one, while acknowledging the efficacy of modern rifle fire, recognizes at the same time the danger from field artillery fire and from night attacks or attacks prepared for by night advances. In the actual selection and preparation of a line of land defense the more moderate view must be accepted, not only for the reasons just stated above but also because the desirable field of fire can not always be obtained, and because the quality of the defenders is not uniform and cases are not unknown where parts of the defending troops have not stood to receive the close attack and thus develop the real strength of their small-arms fire.

The reasons given for the existence of strong points in a line of defense therefore may be admitted to exist to-day as they have in

the past, but the changes in the reliability and range of the attacking artillery and in the tactics of field artillery on the defense have materially changed the form, location, and qualifications of these points in the line of defense.

The term redoubt has become so firmly attached to that old form of work in which artillery held a prominent part, and the different forms are so definitely fixed by the names of their designers, that the word no longer expresses the idea that is intended by those who admit the necessity of strong points in the line of defense but who have altered their ideas as to the qualifications necessary to adapt such points to the requirements of modern war. For this reason the term redoubt has been discarded by many writers in favor of such terms as "supporting points" or "ring trenches," the applicability of which will appear later.

Admitting the necessity of increasing the strength and prolonging the resisting capacity of certain points of a line of defense, without which admission there can be no discussion, what are the characteristics of such points?

Every type of fortification can be discussed under three subjects which include all points in connection therewith: first, the development of fire; second, protection to the defenders; and third, communications.

The development of fire can be classed under the heads of artillery, small-arms fire, and observation points; the protection to the defenders as against projectiles, visibility, and sudden attack; while the communications relate to the control of the troops by their commander, the disposal or care of the wounded, and the reinforcement of the trenches. Incidentally, the subject of the comforts and necessities for the garrison comes in, but these can be considered under the head of visibility, upon which they largely depend.

The placing of artillery in a redoubt has been abandoned in favor of the intervals between the supporting points and of points behind the line of defense, and can be dismissed from the discussion. The number of men that can fire from a given length of parapet is limited physically and can be no greater in a supporting point than in an ordinary trench; the number of tiers of trenches facing the front can be increased at will in an open line of trenches as well as in a supporting point, and it will thus be seen that a supporting point can give no greater amount of fire to the front than a line of trenches along the same ground. One of the essential

qualifications of a redoubt was that it furnished a resisting point even after a part of the trench line had been carried, and this qualification, which still holds good, requires a supporting point to be secure against flank and rear attack and necessitates a fire in all directions, though the difficulties of defense against attack from these two directions are considerably less than against a frontal attack, because the artillery of the attack must cease firing if its

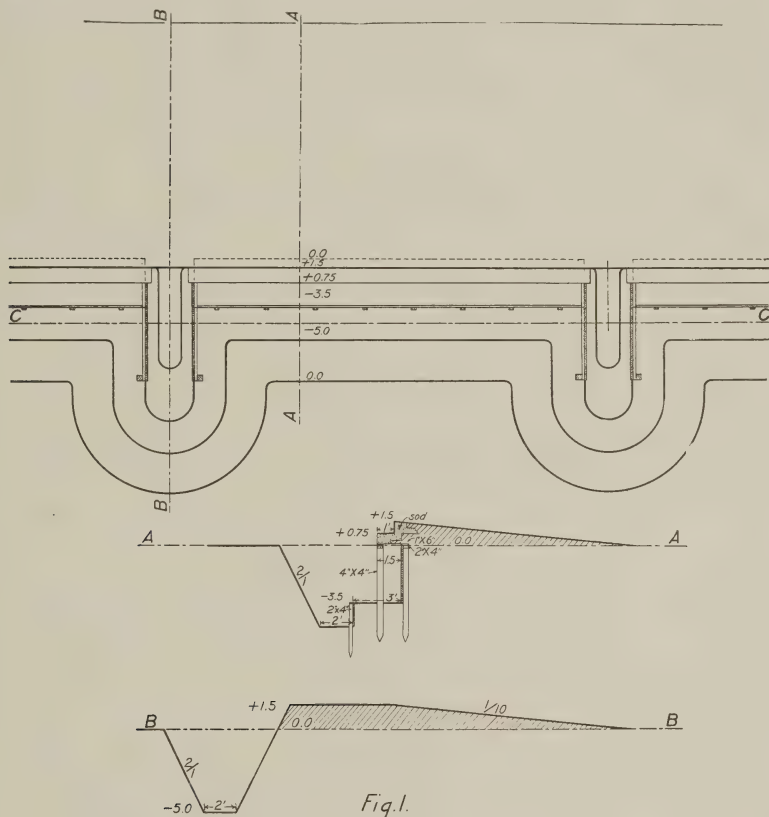


Fig. 1.

troops have broken the line of defense and are mingled with the defenders.

For observing the effect of the defenders' fire, there must be suitable observation stations, protected from the sight of the enemy, yet completely covering all possible lines of attack.

The protection against projectiles can be considered as against curved fire, rifle fire, and hand grenades. Protection must not interfere with suitable fire delivery, and therefore protection against

curved or high-angle fire can not be given to all parts of the firing line of the supporting point, but must be confined to a limited part thereof which can be called the bombproof as heretofore. Since it would interfere with the fire requirements it can not be in the front line of trenches, but must be in rear thereof. These bombproofs should be made secure against field artillery and against siege artillery also, if time permits.

Reasonably accurate artillery fire at ranges up to 2,500 or 3,000

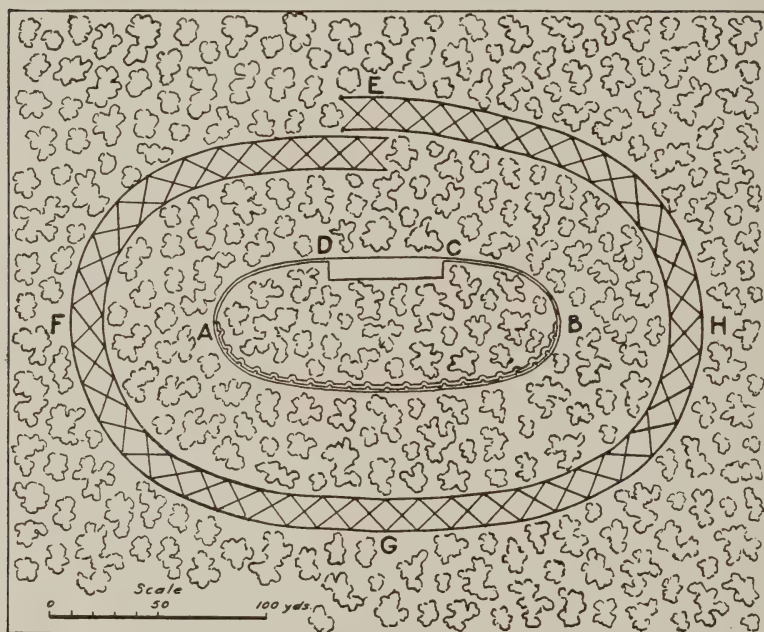


Fig. 2

yards will strike within a bracket less than 50 yards long, and this uniformity of fire and fuses makes one of two trenches 50 yards apart out of the danger area for fire aimed at the other. This 50 yards is therefore a controlling distance, and trenches nearer together than that lie within the probable bracket and all shots within this bracket have a double target and double chance of being effective. Therefore, the bombproof or any second line of trenches must be at least 50 yards in rear of the front line, and this distance is the smallest allowable depth of the supporting point. The same reasoning fixes the back line of trenches, designed for fire to

the rear. It must be either at least 50 yards in rear of the bombproof or must be on the same line with it.

The limited strength of the garrison and economy of labor usually combine to locate this rear line in prolongation of the bombproof, and it will be found very easy to arrange the steps at the back of the bombproof so as to form part of the back trench line. The foregoing considerations make the smallest redoubt 200 yards in perimeter. When occasion requires that all this perimeter be held, the artillery fire will have ceased and a smaller number of men can deliver a greater volume of fire in all directions than they could when subject to artillery fire, and 150 men, protected by

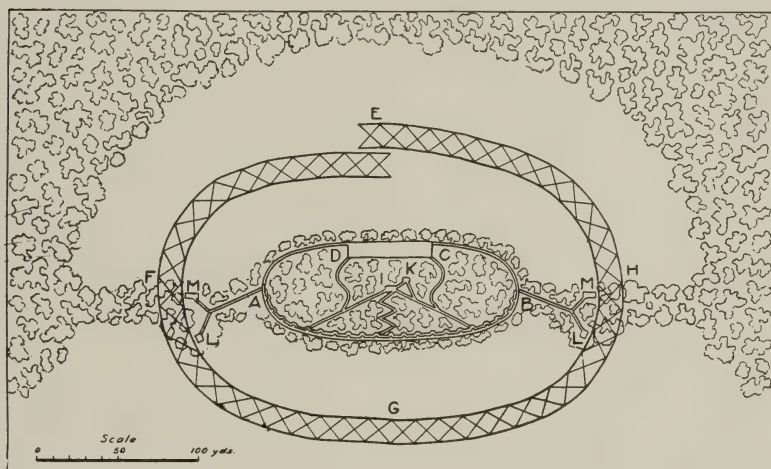


Fig. 3

trenches and obstacles, can easily hold such a work against a daylight attack. The area involved in a supporting point for larger numbers limits the size to about 400 men, since with one man to every 4 feet of parapet such a work would have a perimeter of about 550 yards and occupy an area about 200 by 75 yards.

Local accidents of the terrain may increase this perimeter in exceptional cases, but the endeavor should be to construct the supporting points so that this perimeter shall not be exceeded. The normal garrison should be sufficient to man the front half of the supporting point, trusting to the reserves to man the rear half.

The accepted type of trench (Fig. 1) gives as complete protection against artillery fire as can be obtained and not interfere with the fire delivery of the defenders. The depth of the trench

must protect a crouching man from projectiles having a fall of 1 on 3. The superior and exterior slopes must not be steeper than 1 on 6. This slope will cause most field artillery projectiles to ricochet when fired at ranges under 3,000 yards, and the thickness of the parapet becomes of minor importance so long as the roof of the splinter-proof is not crushed in by the blow of the projectile. The thickness of parapet renders the small-arms bullet practically harmless to a man under the splinter-proof.

Most artillery projectiles will ricochet when the striking angle is less than 17 degrees, but it can not be claimed that every one will ricochet and some means must be adopted to localize the effect of such shots as penetrate the parapet. The frightful effects of the high-explosive shell and shrapnel in the trenches at Fort Riley emphasized this point, and to meet this danger the trenches exposed to artillery fire while occupied must be traversed. The distance apart of these traverses is controlled by two opposing requirements. The closer together they are, the more local will be the effect of the explosion of a projectile, but the less will be the supervision of the officers and non-commissioned officers over the men occupying the trenches. A compromise between the two requirements leads to an interval between traverses of about 9 yards. The traverse being 1 yard thick, leaves 8 yards of parapet to be occupied, and forms a section of parapet suitable for one squad with the squad leader to supervise and control.

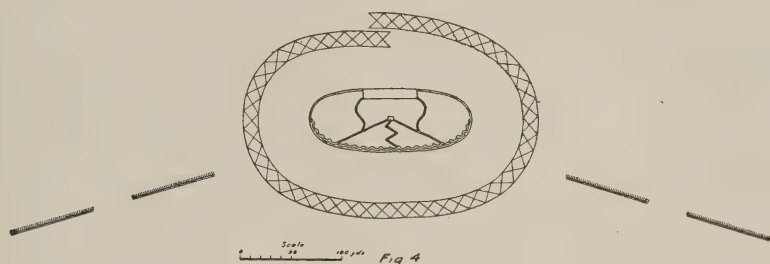
This is the arrangement along the line to be occupied during the frontal attack. The flank and rear trenches, which will only be occupied after artillery fire must cease, need not be traversed; or, if traversed, the interval between traverses can be materially increased. Communication trenches are zigzagged or curved to protect from enfilade and, hence, require no traverses.

Protection against the hand grenade sounds almost medieval and yet it became quite a controlling factor in the location of obstacles during the Russo-Japanese war, where it was found that they could be thrown 30 or 35 yards and that their execution was great when the distance between the obstacles and the trenches did not exceed that distance.

The use of obstacles is to protect against sudden attacks, and so has a very important role in connection with supporting points. The type used varies with the race. The Russians have used military pits more than any other form, but the consensus of opinion elsewhere seems to accept the high barb-wire entanglement as the

most efficient and the easiest and quickest to construct. The width should be from 30 to 50 feet. Since one way to destroy wire entanglement is by high-explosive shell, it should be at least 50 yards from the trenches to protect it from artillery fire aimed at the trenches and, also, to prevent the enemy from throwing hand grenades from its outer edge into the trenches. On the flanks and rear, when well protected from sight, this width may be diminished, although the danger from hand grenades would be then increased.

Whatever class of work be used, every practicable precaution must be taken to decrease its visibility to the enemy. The use of sod, grass, branches, etc., are all described in military works, and the one appropriate and convenient to the site must be used. Every artificial feature of the work must be concealed as far as practicable, and advantage will be taken of every natural concealing feature, because it lessens the work of the troops and be-



cause a natural screen is less liable to attract the eye than an artificial one.

The necessary communications consist of the telephonic or telegraphic communication with the rear and flanks and the communicating trenches leading into the supporting point and connecting the various parts of that work.

The electrical communications mentioned are the same, regardless of the type of work.

The trench communications must offer a secure entrance for reinforcements and a safe means of passage about the interior of the work for reinforcing the different parts, for the passage of the officers while controlling the troops, and for the removal of wounded. The flanks of the supporting point afford two easy entrances to the front trench and for most works they will be sufficient for that purpose, although in very large ones there may need to be another one across the middle of the work.

The best point for the commanding officer is probably the center

of the supporting point. From this point his voice can usually be heard at all parts of the supporting point and he can keep good control over his troops. Near by and connecting with the commander's station will be the telephone or telegraph station. The dressing station can be put in one end of the bombproof.

The bombproof must be connected by a communicating trench with the cover in the rear to afford safe passage to and from the supporting point. The questions of latrines and kitchens are disposed of in the manner that the local conditions dictate, due regard being given to the comfort of the men and the cover obtainable.

Having now discussed the various requirements, let us see how to accommodate them to the ground. Figure 2 is a wooded site

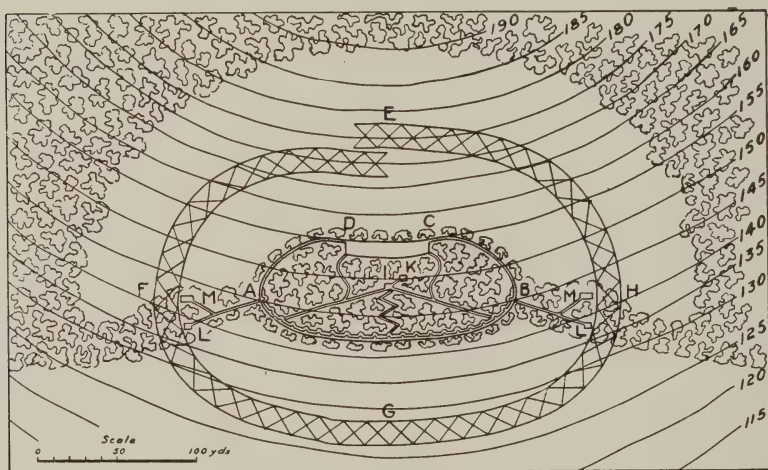


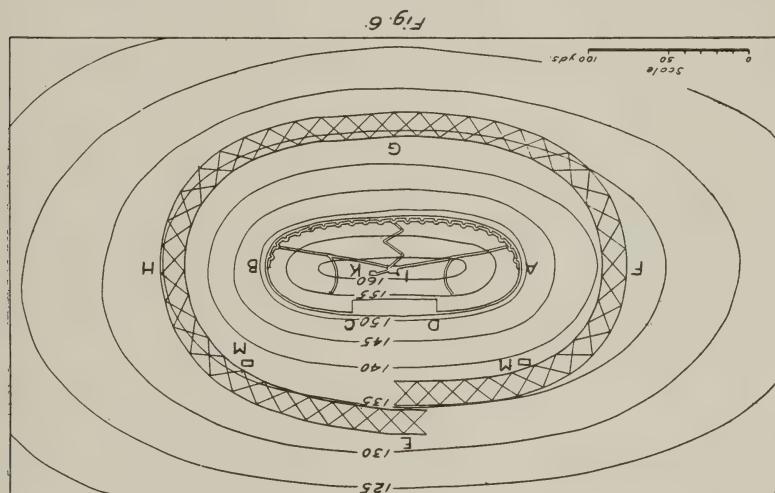
Fig. 5

upon which it is decided that a supporting point must be placed capable of holding two companies of infantry of 128 men each. It is not steep enough to accommodate more than one tier of fire. The best frontal fire we can get then will be from about 128 men in a trench about 160 yards long, indicated by the line AB. This must be connected at the ends with a rear line at least 50 yards farther back and shown by BCDA.

The line AB is a traversed, splinter-proof trench, the lines BC and DA are untraversed trenches; CD is a bombproof. The wire entanglement must be at least 50 yards in front of the trench AB; in rear it may be closer, though not so made here. EFGH is the position of this entanglement.

The latrines are located at M, Fig. 3. The observation stations are at L, Figure 3. The supporting point should have water piped into it and its permanent garrison should live on the site, though not in the bombproof until necessary. The work should be done by the troops that are to occupy the position.

The amount of clearing required is shown in Fig. 3, which also shows the communicating trenches and the commanding officer's station, I, and the telephone station, K. The dressing station is in the bombproof. This form of clearing opens up the field of fire to front and rear, but does not make any break in the continuity of the timber line nor do away with the advantage of the cover from view afforded by the woods.



The Russian redoubts in Manchuria were first placed well to the rear of the line of trenches, but as the war continued they put them closer and closer to the line until, finally, they were placed directly in the line. This is the usual rule deduced from reasoning on the subject. There are occasional places in a line where it seems best to put the supporting point in rear of the line, or, rather, to put a line of trenches in front of the work, for the location of the flank trenches, as a general rule, should be such that they are enfiladed or commanded for at least 300 to 400 yards each side of the supporting point. Trenches in front of a supporting point, as a rule, can only be used advantageously when the ground in front has a very sharp slope with a flat open field of fire in front. Fig. 4 shows the arrangement of a supporting point and trenches adjacent.

The best location for the trench line has been argued oft and long. The main difference of opinion is whether to occupy the military crest of a slope, or to occupy a line near the foot of the slope. Some on each side advocate a secondary line in rear of the front line. Regardless of the merits of either location of the trench line, the supporting points will lie in or very near the forward line of trenches, except in the case where the top of the hill or ridge must be held to prevent the enemy from obtaining it for observation purposes or where it would give him command over a long section of the line of defense. The supporting point should never be on the secondary line in the rear.

A recent study of about eighty sites for supporting points showed

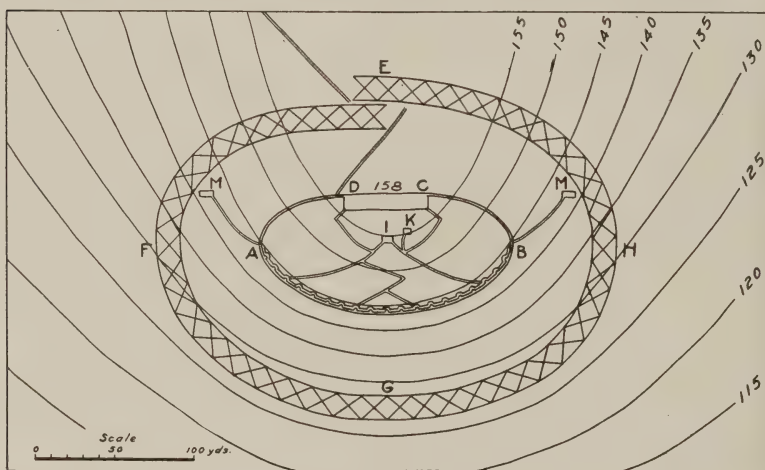


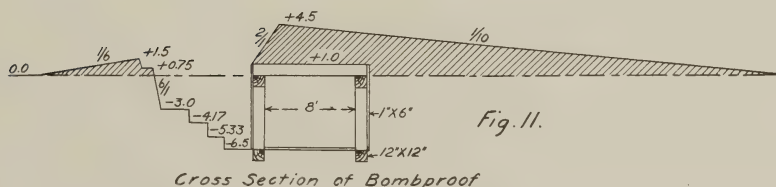
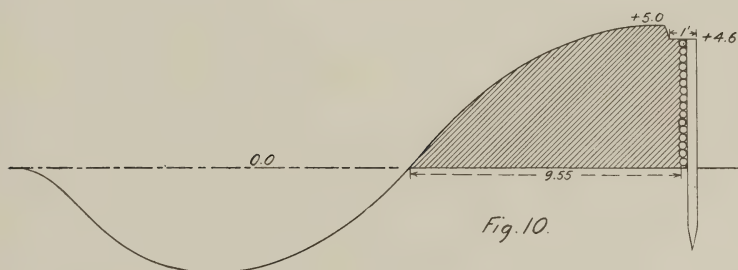
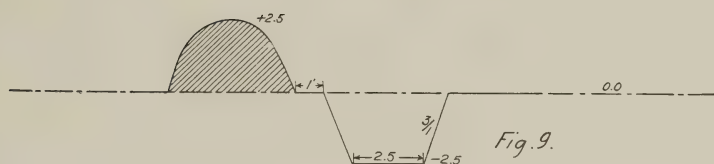
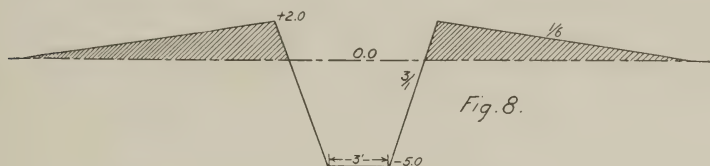
Fig. 7

only three distinct types of location. The first was a wooded side hill where it was out of the question to go to the top of the hill. This was solved, as shown in Fig. 5, practically as though it was on a flat plain. If the hill is not wooded this treatment will not answer, and the top must be held unless it is under a good fire from some near point of equal or greater elevation.

The second was a ridge or hill where it was thought best to occupy the top, and is shown in Fig. 6. This is probably the ideal situation, since the work on the bombproof is a minimum and the approach from the rear is completely covered. The case of a ridge is much more general than that of a hill just suited for the supporting point, but both cases are handled in the same manner.

The third was a spur where it was thought best to occupy the top,

and is shown in Fig. 7. Two machine guns were placed in all supporting points and three in some of the larger ones. They were usually placed on the flanks of the front line. Special emplacements must be provided if the wheeled type or the tripod type of



machine gun is used, and difficulty will be experienced in getting the guns in and out of the trenches. The new, Benet-Mercier, type requires no special arrangement of the parapet.

The front line of all types follows a contour, but rises sharply on the flanks where necessary. The rear line should have a clear field

of fire of at least 100 yards and the obstacles must be under fire from the trenches at all points.

The communicating trenches, when in the open, must be approximately of the section shown in Fig. 8, and within the area of the entanglement must be completely screened. Outside the supporting points the communicating trenches need not be so completely concealed. If well screened naturally, they can be simply protecting parapets (Fig. 9). The same is true of the trenches making up the supporting point. They vary from the type shown in Fig. 1, used on an open slope exposed to view, to that shown in Fig. 10, which can be used in the edges of woods. A type similar to Fig. 10, made of bags of sand, will have to be used on a rocky site where little or no soil is available. Wherever concealment is rendered complete by a natural screen this form of parapet is excellent, because there is no trench to fill with water during rains.

A section through the bombproof of an open side hill work is shown in Fig. 11.

In considering the foregoing, it must be remembered that the supporting points just described have no connection with the subject of permanent land defense, but apply only to such semi-permanent works as would be used in the hasty defense of a position. Bearing this fact in mind, it is believed that an analysis of the characteristics of the supporting point advocated herein will show that it possesses all the requirements of a strong resisting point in a line of defense compatible with a line of field fortifications; and that the objections to the old forms of redoubts have practically all been removed, while the strength that they conferred on a line of defense has been retained.

DISCUSSION

LIEUT. COL. J. E. KUHN
Corps of Engineers

The fundamental principles affecting the requirements of "supporting points" in a line of defense are essentially the same to-day as in the days when the more or less conventionalized form of "redoubt" had its origin. The "ring trench" with its accessories, as advocated in the foregoing article, represents merely a development imposed by improvements in weapons and changes in tactics, as well as by the better understanding of the functions of fortifications in general. Although differing so widely in form, analysis will show that

the stereotyped geometrical "redoubt" and the more modern "ring trench" possess the same elements designed to meet the same requirements.

It is unquestionably true that the term "redoubt" has, unfortunately, become associated with a symmetrical geometrical trace. This conception is, however, erroneous, and is the result of confusing form and essence. For the same reason, the use of the term "ring trench" is to be deprecated as tending to a fixed form of trace for the fire line of a "supporting point."

So far as principles and functions are concerned the "ring trench" with its accessories is as much of a redoubt as are the older geometrical forms. But after all, names count for little providing the essentials are not lost to sight. With this understanding, it will be readily understood that there is no inherent virtue in any particular form of trace for the fire line of a supporting point. While this trace will ordinarily be a closed curvilinear figure, there is no reason why it may not consist wholly or partly of straight portions, or even of a series of disconnected trenches located with regard to the topography and fire requirements.

Regarded as types rather than as fixed forms, "ring trenches" of the character shown in the drawings certainly fulfil all the requirements for supporting points in a defensive line and this, too, in the simplest manner possible. They are in agreement with the latest published ideas of the Germans, who consider them applicable both to permanent works and to field works.

As compared with the former redoubt, the "ring trench" type of supporting point presents the following differences among others:

1. The avoidance of any pronounced relief in parapet and accessories.
2. The abandonment of the ditch as an obstacle.
3. The use of a traversed fire line.
4. The fuller development of the communications.

These differences are but the result of logic applied to the consequences of improvements in weapons, mainly field artillery.

So far as the effect of artillery fire up to ranges of 3,000 yards is concerned, it is not thought that placing the rear fire line at a minimum distance of 50 yards from the front line is a matter of great importance. At ranges within 3,000 yards the angle of fall of artillery projectiles is such as to insure deflection with little material damage to works of low relief and flat slopes. As the rear fire line will ordinarily not be occupied by troops until after artillery fire has ceased, it must be evident that the minimum prescribed distance of 50 yards is relatively unimportant, the supposed advantage of which may, moreover, be partly nullified where the work is located on ground sloping toward the attack or where the latter can occupy commanding ground within the assumed range of 3,000 yards. The results of experience in the Russo-Japanese war, as well as the experiments at Fort Riley, have fully confirmed the invulnerability of field works against the lighter forms of field artillery hitherto employed by field armies. The recent introduction of heavy calibers of mobile artillery with field armies introduces a new element in the problem which requires careful consideration. The Riley tests have shown that long-range fire from heavy guns and curved fire from howitzers, with improved projectiles, is capable of inflicting serious damage upon field works, and that protection from such fire is ordinarily beyond the limits of field construction. The very fact, how-

ever, that this damaging fire is curved or long range greatly diminishes its accuracy, and the bracket will greatly exceed 50 yards.

Bombproofs of the type shown in Fig. 11 afford no protection against the new type of artillery fire and must, ordinarily, take their chances. To minimize damages due to lucky hits, it is thought desirable to construct a number of smaller bombproofs judiciously scattered within the interior of the supporting point, rather than one large one as shown in the drawings.

With a parapet essentially the same as that employed in the general line of trenches, the strength of a supporting point against frontal attack depends primarily upon the field of fire and the surrounding obstacle. The former is a question of location and clearing, the latter of thorough construction. The value of the obstacle as an element in a supporting point is all important and can not be too strongly emphasized. The minimum distance prescribed for the line of obstacle is logically correct. The maximum distance should be such that hostile artillery fire must cease before the attacking troops can reach the obstacle, a distance which will vary according to topography. Ordinarily, it should not exceed 100 yards.

The accuracy of field artillery at short and mid ranges is now such that the attacking infantry can be supported to within a short distance of the object of attack. Unless the defending troops can man the fire lines under hostile artillery fire, a large portion of a clear field of fire may be sacrificed. The front fire line should therefore be provided with some form of headcover to enable the defenders to stand up to their work. The best form for such cover is a mooted question, but it is thought sand bags or small portable plate-iron shields offer a better solution than more elaborate constructions of timber and earth, such as used in Manchuria and which the Riley tests showed could be quite extensively damaged by short-range fire from light field guns with considerable losses to the personnel.

The types of supporting points shown in the several drawings are unquestionably well suited to their objects, but they should be regarded as types and not as fixed forms any more than the earlier forms of symmetrical geometrical redoubts.

MAJ. C. A. F. FLAGLER

Corps of Engineers

Land defenses at present appear to require subdivision into three classes:

1. Permanent defenses erected in time of peace around strategic points.
2. Works erected during the period of hostilities, but not in the near vicinity of the enemy, and with considerable time, materials, and civilian labor available. The term "Provisional Fortifications" has been applied to these.
3. Field works and trenches erected generally by the troops, more or less hastily, with the materials locally available, and in the immediate field of operations.

The ring trenches in the article appear to belong to the third class. Their design shows a step in the line of progress, but in my opinion a very short one. There is no doubt that "supporting points" are still essential in any defensive position taken up by an army, and the "ring trenches" described are a marked

improvement on the typical redoubts, which have generally been too compact, too conspicuous, and too laborious of construction.

The ring trenches, however, appear to hold to the exploded ideas of continuity of trench, curvilinear trace, and adaptability of a single type to all sites. If we have an exterior obstacle, continuity of the obstacle is all that is necessary to make a closed work, and, while there is no objection to a continuous trench *per se*, there is no value in it, and adherence to it frequently weakens the development of fire. The curved trace is objectionable in that it is more difficult to determine in advance the effectiveness of the fire in any given direction. Furthermore, as the fire diverges from the normal to the crest of the trench, men feel handicapped as compared with those on the normal, and do not take the same care in firing; further, they feel that they are more exposed. Both of these conditions are aggravated if loophole or shrapnel cover is used. The adoption of a type to fit all cases is very objectionable. It has its value if we assume that supporting points are to be fortified by men lacking in ingenuity, intelligence, and education—not otherwise. The best results will be obtained only by a tactical selection of the supporting points as determined by an inspection of the terrain, and then by a special trace for each point, in which development of fire in all desired directions is the only consideration. This trace should consist of sections of trenches, always straight unless too great labor is involved. The trenches may be in tiers, may join each other at the ends, may overlap, may be intended only for alternative occupation. The firing trenches located, attention can be given to location of communicating trenches; obstacles, bombproofs, lookouts, signal stations, latrines, support and reserve trenches, and drainage.

The communicating trenches should be constructed with offsets at short intervals, whether oblique or normal to the front of the line, as they may be entailed at some stage of the attack, whatever their direction, and the offsets will offer secure halting places at intervals in their passage.

The obstacle may be curved or straight. The best obstacle, all points considered, is doubtless the wire entanglement. It is my belief that this will be more effective for the same amount of wire if made in two lines, the inner line some 20 feet from the outer, and only about 7 feet wide; the outer to be as wide as time and materials permit. This arrangement is suggested to enable the defenders to retain their confidence in checking the attack up to the complete passage of the outer line. If the attack is pushed to a finish the wire entanglement can be cut with nippers at the rate of 20 to 30 feet a minute. An attacking force that has passed the obstacle is not likely to be repulsed at the crest, and the difficulty of determining how far through an entanglement the attack has progressed at any point is likely to shake the morale of the defenders as soon as cutting begins, and diminish their effective fire at this important stage; whereas a second line, however light, will be likely to stiffen the defense until the penetration of the outer line is actually completed. The vital features of the trenches are that the interior slope should be as nearly vertical as possible, and that all trenches should be provided with overhead shrapnel cover. This need be no more than one layer of planks, 2 or 3 feet wide, with a few inches of earth on them. This is a complete protection against shrapnel. Troops so protected can not be shaken by artillery fire until the cover is des-

troyed by direct hits, a tedious operation, as shown at Fort Riley in 1909. Furthermore, if the fire slackens at any time the cover can be quickly repaired.

The bombproof section (Fig. 11) is very light. A bombproof should be bomb proof. Results at the Fort Riley tests lead to the conclusion that a minimum vertical cover of 12 inches timber and 10 feet earth is essential to withstand the heavy field artillery that will accompany modern armies, such as our 4.7-inch rifle and 6-inch howitzer. The term "siege artillery" is becoming obsolete.

The presentation of the general features and requirements of works of this class in the article appears to me excellent.

MAJOR THOS. H. REES

Corps of Engineers

While agreeing in general with the deductions and conclusions of the author of this paper, I find that I differ with him on some points that are quite important, viz: the depth of the trench, the location of the bombproofs, and the communications.

Artillery hits for a single gun may be bracketed within a space of 50 yards in the direction of the line of fire when the target is a distinct point, and when hits can be observed and overs and shorts reported to the gun after each shot. With an obscure or indefinite target and without accurate knowledge of overs and shorts, the hits would more likely be included in a bracket of 150 yards or more. In fact, no definite distance can be stated as the bracket for hits at different ranges and for varying conditions, and it is better to give the entire work the least possible depth rather than to spread it out in an attempt to place the bombproof beyond the bracket of shots aimed at the trench.

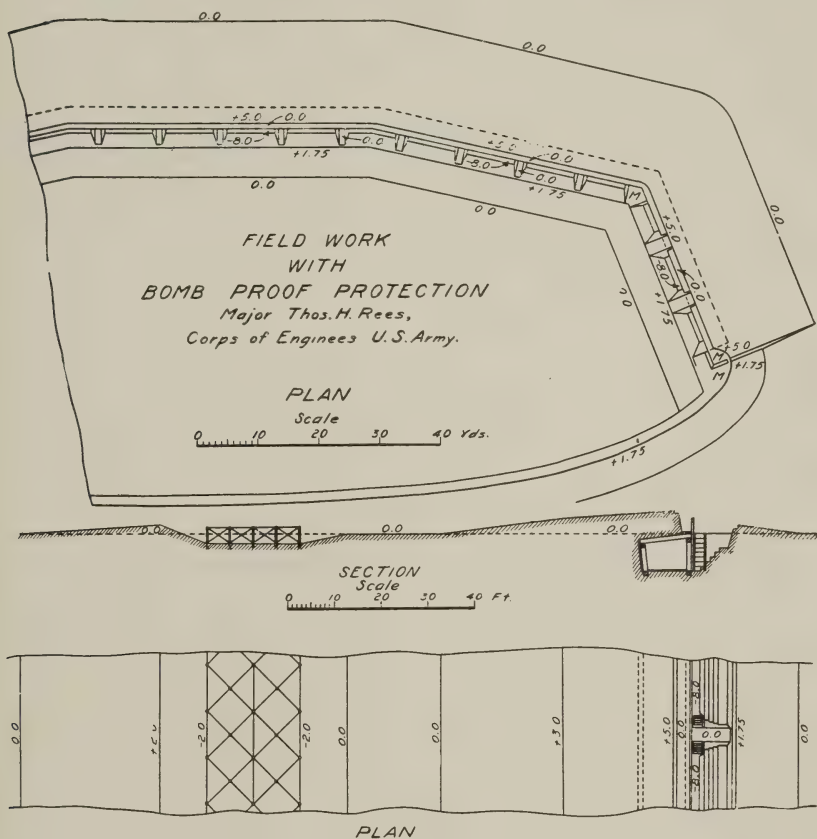
Under a bombardment by shell and shrapnel, the garrison will be in the bombproofs and hits on the trench will cause no casualties and will do no damage, except to displace some earth which can readily be replaced and which will not destroy the trench as a defense against infantry attack.

The artillery attack will cover the approach of infantry to within 200 yards of the work, when the artillery fire will cease and the infantry will attempt to rush the work. At this instant the crest of the work must be fully manned to repel the attack and every second's delay will be so much gain to the enemy. If the crest of the work is 50 yards from the bombproof, it will be from 100 to 150 yards by way of the zigzag communication and around the ends of the traverses to points on the crest. The attack will advance in line, at a rush. The defenders must trail along in single file through the narrow zigzags. Unless delayed by obstacles, the attack would reach the crest of the work in overwhelming numbers simultaneously with the defenders and the work would be captured. It is essential, therefore, that the bombproofs shall be close to the trench and that the communications shall be short, ample, and direct.

The trench should be deep enough to shelter a man standing, and the crest should be high enough to see over the grass, weeds, and brush, and over the entanglement in the foreground. In the trench described by the author, the depth below the crest is 6.5 feet, and a 6-foot man standing 3.5 feet from the crest would not be sheltered against a grazing shot with a 1 on 3 fall. A crouching position should not be required. The height of para-

pet above the surface is only 1.5 feet, which is not sufficient to see over the grass or other growths or over slight folds of the ground in front. On target ranges, although the firing points are built up a foot or more above the surface, and the targets are considerably elevated, it is necessary to keep the grass mown in order that the targets may be seen. The crest should be at least 3 feet above the general surface of the ground.

The small recess shown behind the parapet is of no special value and it



weakens the parapet. For ammunition recesses a number of boxes let into the interior slope will suffice. A deep trench is safe against shrapnel fire and the recess does not add to safety against high-explosive shell.

A high entanglement, if unscreened, is the most conspicuous element of this type of work. If screened, this would also screen the foreground from a low (1.5 feet) parapet. The best arrangement for the entanglement, if time permits, is to place it in a shallow ditch, using the earth to form a glacis in its front. This, of course, adds largely to the amount of labor required, but with teams, plows, and scrapers, such work could be quickly executed, and would add very much to the security and invisibility of the work. Moreover, the work

that requires the greatest labor and longest time is the construction of the bombproof, and all the other work can be completed in the same time.

The earth cover of the bombproof is itself an excellent parapet and there is no reason why it should not be so used and constitute the main parapet of the work. By so doing, every shovelful of earth moved serves a double purpose in increasing the capacity and cover of the bombproof and in strengthening the parapet. The front trench, with its traverses and the zigzag communications leading to it, will be eliminated, and the garrison will be ready on the instant to man the parapet and repel an assault.

Traverses will be formed by leaving in place masses of earth at suitable intervals along the trench behind the bombproof. On the flanks of the work these traverses should be built up to the height of the interior crest, but on the front faces their tops will be at the natural surface of the ground or at the level of the banquette. The rear side of the bombproof trench may be finished with a low (1.75 feet) parapet for gorge defense or, when necessary, the gorge may be closed by the ordinary standing trench placed from 50 to 100 yards in rear of the front parapet. At the shoulder angles and at the ends of the gorge places are provided for machine guns.

Drawings are submitted herewith which illustrate a type of fieldwork considered reasonably safe against siege artillery. For safety against light artillery a lighter parapet and less overhead cover would suffice.

CAPTAIN G. A. YOUNGBERG

Corps of Engineers

“Simplicity is the first principle in making successful war.”

There can be no question that the works discussed in this article conform to the above dictum, and yet, in departing from long-established type forms, it would appear that no essential element has been discarded.

While the ideas expressed in the article and illustrated in the sketches may appear radical to many of us, they will be found to be no more than abreast of the most modern European practice and correspond very closely to the German regulations as well as to those of the Russians, whose experience has been the most recent and whose aptitude for field fortification is historical.

These “ring trenches” or, by whatever name works of this character may be designated, very forcibly illustrate in the field of fortification the tendency to depart from stereotyped forms—the so-called “normal” or “type redoubt.” The same idea finds expression in tactics in the abandonment of the “normal” attack, the “normal” outpost formation or advance-guard, and calls attention to the necessity of deciding each case on its merits—the adaptation of the means at hand to the situation as it actually exists.

These works also indicate the decentralization of command and dispersion of control of the firing line, that is to say, the division of the defending forces into small groups, as sections or squads. The responsibilities of the group leader are in consequence much greater, and the importance of good judgment on his part, of his capacity for exercising intelligent command, and of his general training, is correspondingly increased.

The number and frequency of traverses in order to localize the effects of artillery projectiles must be compromised with the necessity of keeping units

intact and reducing to a minimum the number of semi-independent commanders, as well as retaining a maximum effective frontage of the firing trench for any given perimeter.

With reference to communications, it is thought preferable for the sake of uniformity to conform to the phraseology of the current edition of Field Service Regulations, wherein electrical or other means for the transmission of information and orders are spoken of as "lines of information," the term "lines of communication" being reserved for use in connection with lines of supply, whether the supplies be reinforcements, subsistence stores, or what-not.

Finally, a point of support has no value except as an instrument, a material means to a definite end, and that end is to gain time. Accordingly, the success of the defense may well be measured by units of time gained for the concentration and organization of the mobile field army, which, assuming and successfully maintaining the offensive, can alone decide the ultimate issue.

CAPT. C. O. SHERRILL
Corps of Engineers

The position taken by the author in reference to the necessity of strong points appears to be perfectly sound, and too much stress can not be laid on the subject of the proper location, tactical use, and design of such works.

The term "redoubt" for these strong points would be misleading in that this term would at once convey to the reader a certain particular form of defensive work, rather than the general nature of such positions and the kind of defensive action desired there. The terms "fortified pivot" or "supporting point" seem to best describe the general method of treatment desirable. These fortified pivots may then vary in type, depending on the terrain and the tactical situation, from a permanent concrete fort to the simplest lunette in which splinter proof and head cover only are provided, and yet a clear idea of their function will be conveyed.

In reference to the particular type of these works desirable, it appears that the article does not bring out the circumstances under which open works (lunette type) should be used for these fortified pivots. Except on the flanks and in isolated positions not covered by a retrenched line in rear, the open work seems to be generally preferable for a fortified pivot, because of the ease with which an enemy can be driven out of such a work by a concentrated fire from a trench in rear of the pivot. On the other hand, let the enemy once secure a footing in a redoubt with ready prepared fire trench faced to the rear, and he is prepared to offer a stubborn resistance to all efforts of our supports to displace him. This principle is well illustrated by the many unsuccessful attempts of the Japanese to take the Russian trenches at Kinchau, where the pivots were open works connected by trenches of slightly concave trace starting at the gorge angles, with a second line of works in rear of and commanding the interior of the lunettes. That is, the pivots were well to the front so that it was impossible to launch an attack against the intervals before the pivot was taken; and the interval trenches, being of slightly concave trace toward the

front, offered an effective flanking fire across the front of the pivot. The fortified pivots thus placed seem to the enemy to invite attack, and being our strongest points, are the ones at which we wish the attack to be made.

At the aqueduct position, at Port Arthur, the fortified pivots were closed works with connecting trenches of convex trace, from which no flanking fire in front of the redoubts was possible. The redoubts were captured and the entire line at once became untenable.

CAPT. J. A. WOODRUFF

Corps of Engineers

This is an excellent article on the design and use of redoubts in field fortification. The general principles of the use of redoubts are in accordance with the views of the most modern authorities, and the type of redoubt shown by the drawings meets the requirements much more completely than any of those shown in our text books and manuals.

There are a few minor details that might be improved upon:

1. The side slopes of the trenches shown in Figs. 1, 8, 9, and 10 should be much steeper than indicated, as they can be made so in most soils, and can even be vertical in clay. This would reduce the time and labor of construction, would simplify the drawings and estimates, and would increase the protection of the garrison from curved fire. It is noted that the slopes, as given in the drawings, vary from 2 on 1 to 6 on 1.

2. The zigzag communicating trench in front of the commander's position (I) is hardly necessary in view of the labor required to construct it.

3. It might be better to combine I and K. In Fig. 7 the communication between them is not direct enough.

4. The new Field Service Regulations give the strength of a company of infantry as 104, instead of 128.

MAJ. WILLIAM V. JUDSON

Corps of Engineers

In my opinion the typical redoubt described excellently meets modern conditions, in so far as they require to be met with closed works in field warfare.

It was my observation, while attached to the Russian army during the war in Manchuria, that the importance attached to closed works, certainly in Russian opinion, steadily diminished as the war progressed.

Two influences have led to the modification of the art of fortification within the past six years. One is a realization of the character and effectiveness of modern artillery fire; the other is the development of the night attack. Suppose we consider these two influences separately and determine the limitations each imposes.

Increase in the rapidity of fire, range, and accuracy of small-arms fire compelled the target, formerly dense columns or multiple lines of troops formed shoulder to shoulder, completely to alter its character. The target for infantry fire may now be regarded as composed of scattered individuals in several skir-

Continued on page 511

REBUILDING THE GALENA LOCK GATES

BY

S. EDWARDS
Assistant Engineer

Galena Lock, which makes navigation possible between Galena, Ill., and the Mississippi River, is located at the confluence of Galena River and Harris Slough, 4 miles west of Galena and 2 miles east of the Mississippi River. The lock was purchased for \$100,000 by the United States in March, 1894, under the provisions of the act of Congress of September 19, 1890.

The dimensions of the lock are 280 by 52 feet. The elevation of the lower miter sill is 2 feet below, and that of the upper miter sill 3 feet above, the low water of 1864. The upper gates are 9 feet by 30 feet 2 inches, and the lower gates are 13 feet 8 inches by 30 feet 2 inches.

During the season of 1909, an examination showed that the old gates, which had been in service since 1890, were rotten and in a dangerous condition, and new gates were regarded as immediately necessary. The old gates were built of white pine, except the toe post, which was of oak, and all of the material on examination proved to be unsound. The material for reconstruction, consisting of Douglas fir, except for the heel and toe posts, and the casing around the valves in the gates, all of which were of oak, was delivered at Dubuque, Ia., where the fir was creosoted and then taken to Galena Lock by barge and there framed ready to be assembled.

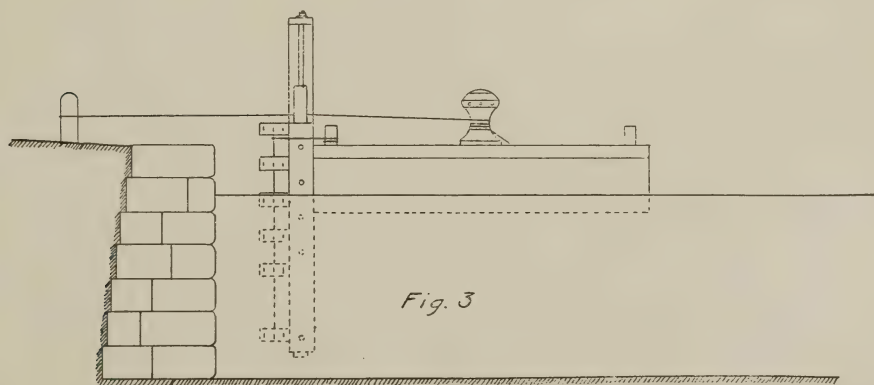
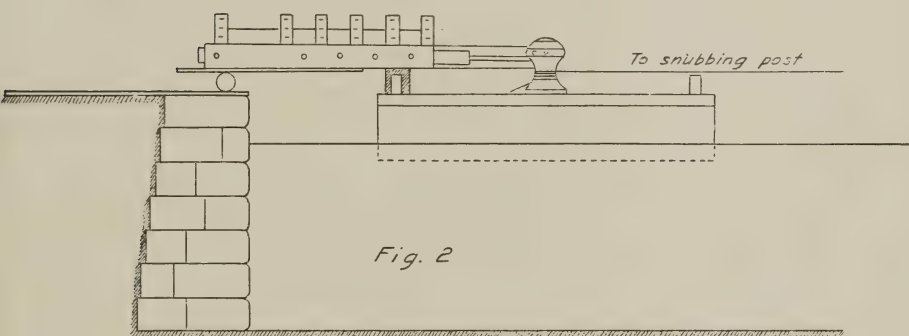
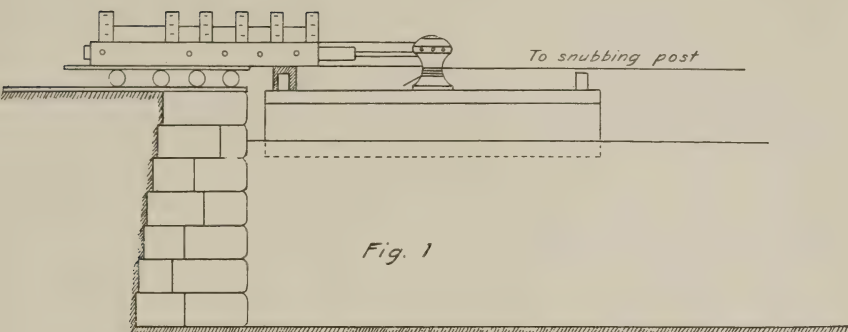
At the close of navigation, cofferdams were built below and above the lock, and the work of pumping out the lock was begun. After a great deal of delay, the water was brought down to the top of the upper miter sill, but, though no leaks were discovered in the cofferdam to account for the apparent impossibility of further lowering the water, all efforts to lower it beyond that point seemed of no avail. In the meantime, the upper gates had been completely removed and the lower ones down to water surface. Subsequently, in removing from the lock chamber some ice, which, owing to fluc-

tuation of water level, was 4 feet thick, it was discovered that the lock floor was leaking, and it became evident that some other method would have to be applied to put the gates in place. It was therefore decided to build the gates ashore and to mount them in place after completion. Accordingly, pumping was stopped, the water allowed to rise, and part of the cofferdams removed.

After careful measurements of the old gates, the new ones were assembled in a horizontal position and completed ashore near the land wall. The remaining parts of the old lower gates were then hoisted out with an improvised derrick. A barge, on which a couple of capstans had been placed temporarily, was taken into the lock, the gates were lowered upon rollers, moved to the face of the lock wall, launched so as to project over the barge about 2 feet, and were then secured with lines to the barge. (Fig. 1.) Other lines were then run from the capstans to snubbing posts on the opposite lock wall, and the barge with the gate was slowly hauled over until the gate slipped off the wall and into the water. (Figs. 1 and 2.) The barge was then moved to the recess, lines were run to the near lock wall, and the gate was forced into a vertical position (Fig. 3), being then guided into the hollow quoin, forced down, and fastened in place. The gates were lighter than water and, with a line, were easily brought and held vertically. It was equally easy to press the pintle down into the socket. The gate was then held by chains while the hinge strap was secured.

As compared with the cost and delay of building cofferdams, the method proved to be simple, cheap, and expeditious, and may be of value to others contemplating like work. But for a delay caused in removing some sediment from the miter sills and recess, all four gates could easily have been hung in two days. The actual time consumed was four days, of which more than half was for the removal of mud. It might be added that the gates mitred satisfactorily. The method for gates of this size is simple, but careful measurements are indispensable.

The original estimate of cost for rebuilding and placing the gates, based on the method finally adopted, was \$3,000. After the preparation of these estimates, local considerations induced a change and the adoption of cofferdams. The cost of building and removing the cofferdams and tearing out the old gates was \$2,319.35. The cost of building and placing the new gates was \$1,906.15, of which \$53.32 was for launching and placing. It is evident that the original estimate was conservative, and that the change of plan led to a considerable and unnecessary increase of cost of, probably, at least \$1,500



AN OUTLINE FOR PRELIMINARY EXAMINATIONS AND SURVEYS

BY

LIEUT. COL. GEORGE A. ZINN
Corps of Engineers

In the paper on the "Advisability of a Waterway Improvement," which appeared in the July-September number of the PROFESSIONAL MEMOIRS, an attempt was made to set forth in a general way the elements which enter into the problem of determining the advisability of improving a waterway. The summary of these elements was brief because the discussion developing the relation of these elements to the general subject, as well as the value of the subject to officers of the Corps, seemed to make a lengthy or detailed summary unnecessary and inadvisable.

In order, however, to make a practical application in preliminary examinations and surveys of the general ideas advanced in the paper, the summary must be greatly elaborated and made to cover every case that may arise. The outlines presented here have been prepared with that end in view.

Advisability is to be determined by balancing advantages and disadvantages. The advantage of a waterway arises from its relative value as a line of transportation; its disadvantage is its relative cost. The value and cost must therefore be ascertained by full and complete investigation, but the extent of investigation required to determine advisability in one case may differ largely from another case. A cursory investigation may show inadvisability in the one case, whereas in another case an extended investigation of transportation characteristics may indicate the necessity for a survey to ascertain the cost of improvement and, hence, advisability. The various classes of cases so shade into each other that it would involve considerable labor to prepare an outline or synopsis suitable for each individual case, nor is it necessary to do so.

An outline or synopsis covering a case requiring a complete in-

vestigation—*i. e.*, both preliminary examination and survey—may be used for minor cases or preliminary examination alone by the selection of items appropriate to the case in hand.

The logical division of a complete investigation into the advisability of a waterway improvement appears to be, first, to develop the transportation characteristics of the waterway, in order to determine its relative value as a transportation line; second, to select the physical characteristics of the waterway necessary for the preparation of a project of improvement; third, to lay down the instructions for the surveyors in making the necessary surveys and investigations to determine the cost of improvement; and fourth, to select a logical order for the presentation of these matters in a report. The general outline is divided in accordance with these ideas into four parts. The outline of physical characteristics follows closely the ideas presented in the "Formulæ of the Characteristics of a Tidal River," given in Mr. Corthell's report on the Seventh International Congress of Navigation, published in Senate Document No. 30, 56th Congress, 1st session.

It may, perhaps, be said that the "Outline for Survey," while indicating the data to be obtained, is silent as to the scope or extent to which the investigations into the physical characteristics should be carried. This was purposely and necessarily omitted. Circumstances connected with each particular case can and will furnish the only guide, but it may be said that in general the data collected should cover the maximum project or improvement desired or indicated, and in such detail that lesser projects may be readily prepared therefrom should the cost of the greater exceed the amount warranted by the importance and value of the waterway from a transportation standpoint.

OUTLINE OF THE TRANSPORTATION CHARACTERISTICS OF A NAVIGABLE WATERWAY

I. Industrial and commercial conditions.

1. How far does the influence of this waterway extend geographically in its effect upon industrial and commercial conditions; in what way and by what agencies?
2. Manufactures, agricultural and mineral productions in the affected territory.
3. Where do these products find a market?
4. Consumption of raw material in the affected territory.

II. Transportation conditions.

1. Rail (or other land) lines.
 - a. Lines (names and kinds of railways, connections, etc.).
 - b. Terminals (side tracks, machinery for handling merchandise, warehouses, elevators, etc.).

- c. Rates, tonnage of traffic, inbound and outbound, origin and destination, classification, etc.
2. Water lines.
 - a. Steamboats, barges, tugs, sailing vessels, etc. Names, length, breadth, loaded draft, cargo capacity in tons. Dates of arrivals and departures for the preceding year and other years, if possible.
 - b. Terminal facilities—i. e., public and private wharves, slips, basins, lighters, machinery, etc.—cost of towing and discharging, wharfage charges, terms upon which the public may use the wharves, slips, etc. Ownership of wharf front, and of space available for wharves.
 - c. Rates, tonnage of traffic, inbound and outbound, classification, origin and destination, cost of transfer.
 - d. Closed season by ice, etc.
3. Combined rail and water lines.
 - a. Wharves, slips, etc. (public and private), machinery, etc., tracks, warehouses, elevators, etc.
 - b. Tonnage of traffic transhipped.
 - c. Classification, origin and destination of traffic transhipped.
 - d. Direction of movement of traffic transhipped.
 - e. Cost of transshipment, and terms upon which the public may use the combined terminals.
 - f. Do rail and water lines prorate?
 - g. Effect of transshipment upon freight movement.
4. Relative distance and cost of transporting traffic between terminals and consignee, in the case of separate terminals (1 and 2).

III. Requirements of commerce.

1. What changes or improvements in present transportation conditions are demanded by commercial interests? (See II.)
2. Reasons for these demands and their interpretation in terms of waterway improvement.

IV. Requirements of navigation.

1. With respect to embarrassments, inconveniences, difficulties, etc., to be overcome.
2. With respect to width and depth of channel, etc.

OUTLINE OF THE PHYSICAL CHARACTERISTICS OF A NAVIGABLE WATERWAY

- I. If a tidal or nontidal harbor, anchorage basin, or harbor of refuge.
 1. Geographical description.
 2. Tributaries, discharge of, etc.
 3. Variations in water level caused by floods.
 4. Periods and prevalence of floods.
 5. Period closed by ice.
 6. Tidal diagrams, mean high and low tide, highest and lowest tides.
 7. Currents, direction, velocity, etc.
 8. Winds, prevailing direction, velocity, etc.
 9. Waves, etc., height, direction, etc.
 10. Material in motion: Amount, nature, source, etc.
 11. Character of bed and banks, materials, configuration, etc.

12. Topography of banks.
 13. Hydrography covering.
 - a. Entrance and exit channels.
 - b. Area used for movement of vessels.
 - c. Area used for anchorage.
- II. If a tidal river.
1. Regimen of the river above its tidal limit.
 - a. Location of source (geographical).
 - b. Length of river and area of drainage basin (tributaries).
 - c. Discharge at low, high, and average stage.
 - d. Periods and prevalence of floods and low stages.
 - e. Materials carried down: Amount, nature, source, etc.
 2. Regimen of the tidal portion.
 - a. Geographical description.
 - b. Hydrography and topography of bed and banks.
 - c. Character of bed and banks (borings).
 - d. Height of banks.
 - e. Indications of variations in the bed, either natural or resulting from works.
 - f. Amount, direction, nature, and source of materials in motion.
 - g. Longitudinal section of thread of stream with lines of low and high water.
 - h. Cross sections at gaging stations, with low and high tides.
 - i. Simultaneous tidal observations at gaging stations every hour.
 - j. Velocity and direction of currents.
 - k. Discharge at gaging stations.
 - l. High, low, and mean tides.
 - m. Limits of propagation of flood tide.
 - n. Diagram of velocities of propagation of low and high tide.
 - o. Period closed by ice.
 - p. Rainfall record.
 3. Regimen of the sea at outlet.
 - a. Geographical description.
 - b. Hydrography of extended area around the outlet.
 - c. Tides, winds, currents, waves.
 - d. Character of bed and adjacent coasts.
 - e. Materials in motion: Bars—their changes.
- III. If a nontidal river.
1. Non-navigable portion.
 - a. Geographical description.
 2. Navigable portion.
 - a. Geographical description.
 - b. Hydrography and topography of bed and banks to bluff lines.
 1. Triangulation and base line.
 2. Levels.
 3. Bench marks.
 4. Cross sections.
 5. Discharge observations.
 6. Velocity and direction of currents.

- c. Length of river and area of drainage basin (tributaries).
- d. Discharge at low, high, and mean stage.
- e. Periods and prevalence of floods and low stages.
- f. Materials in motion: Quantity, character, source, etc.
- g. Character of bed and banks.
- h. Longitudinal profile of thread of stream with water surface at high and low stages.
- i. Cross sections at gaging stations, with high and low water lines.
- j. Gage readings.
- k. Characteristics of outlet (delta, bars, current, etc.).
- l. Characteristics of body of water into which river discharges, so far as they affect the river.
- m. Records of rainfall.
- n. Comparative areas of timber, treeless and cultivated land in drainage basin.
- o. Period closed by ice.
- p. Water power development and other uses of river, not for transportation.

OUTLINE FOR SURVEY OF A NAVIGABLE WATERWAY

I. Survey must cover the following points:

- 1. Observation and measurements should completely develop the characteristics of the waterway under investigation, as shown in "Outline of the physical characteristics of a navigable waterway."
- 2. Soundings must be so distributed as to fully develop the configuration of the bottom, especially where excavation will be required. Hard material to be covered in detail.
- 3. Artificial obstructions and difficulties to navigation, such as bridges, piles, wrecks, etc.
- 4. Stream flow measurements, etc. (See River and Harbor Bill approved June 25, 1910.)

II. Map (see G. O., No. 9, 1910, Office Chief of Engineers):

- 1. The map must show—
 - a. Wharves, slips, basins, warehouses, etc., on the waterway.
 - b. Railway lines near to or connecting with the waterway.
 - c. Special rail and water terminal facilities.
- 2. No single drawing, whether on tracing linen or drawing paper, shall have greater outside dimensions than 35 by 47 inches.
- 3. The exterior limits of a drawing shall be indicated by a black line at least 1 inch from the edge of the linen, or paper, except at the left hand edge when the top edge of the drawing is longer than the left hand edge, or at the upper edge when the side length of the drawing is greater than the top length, in which case a margin of 3 inches shall be left for use in filing.
- 4. Drawings shall, if possible, be so oriented that the top is north, the right hand east, etc.
- 5. In general, the scale of the drawing shall be: For topography or hydrography, 1-20,000, 1-10,000, 1-3,000, 1-2,400, 1-1,200, 1-600, 1-500, or

1-300, according to the purpose for which the drawing is made; for details, 1-48 to 1-24; for details of machinery, construction works, etc., $\frac{1}{8}$ to 1-1; for working patterns, etc., actual size. (The metric system is, however, preferable.)

6. A legend, giving full description of its purpose, the names of persons connected with the survey and drawing, etc., work represented, scale, date, index letters or numbers, etc., shall be placed preferably in the lower right hand corner.

III. Triangulation stations, bench marks, etc.

1. Datum plane to be mean low tide as established by Coast and Geodetic Survey or other authority, or by original observation.
2. Permanent gages and bench marks must be established and connected by level lines with each other.
3. Triangulation stations and bench marks must be connected with Coast and Geodetic Survey points where possible.
4. True meridian must be determined where Coast and Geodetic Survey lines are not available.

IV. Instruments, apparatus, etc., to be used (see Hearing's "Notes on Surveys"):

1. Transit, level, current meter, anemometer, stadia rods, tape line. Row-boats, buoys, signal stations. Tide boards, lead lines, boring apparatus. Axes, hammers, drills. Note books. Device for collecting samples of water.
- V. Investigate transportation conditions, as shown in "Outline of Transportation characteristics of a navigable waterway."

SYNOPSIS FOR A REPORT ON THE ADVISABILITY OF IMPROVEMENT OF A NAVIGABLE WATERWAY

- I. Introductory statement of authority and instructions for making the survey.
- II. Brief statement of movements of survey party and of method employed.
- III. Brief description of the physical characteristics of the waterway (see outline of).
- IV. Brief description of the transportation characteristics of the waterway (see outline).
- V. Previous projects for improvement.
 1. Description of the waterway before improvement.
 2. History and description of projects.
 3. Amounts appropriated and expended.
 4. Results accomplished in physical conditions, increased commerce, lower freight rates, etc.
- VI. New projects for improvement to be discussed in accordance with the following outline, the recommended project to be in full detail, others in less detail.
 1. Proposed depth and width of channel or harbor.
 2. Obstructions to be removed.
 3. Artificial structures required.

4. Estimate of cost (to include not only engineering work and appliances required to produce and maintain the desired depth and width of channel or other improvement, but also all other necessary expenditures involved, such as injuries to drainage and sewerage, water powers, land [flowage], roads, buildings, fisheries, water supply, etc.).
5. Explanation of estimate.
6. Most economical method of conducting the work (time required for completion, etc.).
7. Effect upon *present rail and water commerce* expressed in terms of freight rates, and also upon the direction of its movement.
8. Effect upon commerce, manufactures, agricultural, mining, and land values in the way of development or change in present conditions, *i. e., prospective commerce*.
9. Other benefits—safety, security of navigation, etc.
10. Direct comparison of *cost* (interest on investment, annual cost of operations and maintenance) and *benefits*, expressed in the same or similar units.

VII. The various projects to be considered, as indicated in paragraph VI, are as follows:

1. The project which will meet all the demands of commerce and overcome all the difficulties of navigation.
2. The various projects which will afford some measure of relief from the present embarrassments of commerce and navigation.
3. The project which is justified by industrial and commercial conditions—present and prospective.

VIII. Terminal facilities.

1. Relation of existing terminal facilities to the transportation characteristics of the waterway.
2. Probable effect upon the transportation characteristics of the waterway brought about by improved water or combined water and rail terminal facilities.
3. Improvements which should be made in present terminal facilities to obtain the full measure of relief provided by the proposed project for the waterway improvement, and to prevent monopoly.
4. Whether or not the project should be made contingent upon improvement in terminal facilities, to what extent, and by whom; or contingent upon state or municipal aid, etc.

IX. Relation of the proposed improvement to the development and utilization of water power for industrial and commercial purposes, to drainage, to land reclamation, and to such other subjects as may be properly connected with the project, giving consideration only to their bearing upon the improvement of navigation and to the possibility and desirability of their being co-ordinated in a logical and proper manner with improvements for navigation.

X. Summary and recommendations.

EFFECT OF LIGHTNING ON REINFORCED CONCRETE SIDEWALKS

BY

MAJOR CHARLES KELLER
Corps of Engineers

Light-house structures are usually situated at remote and inaccessible localities, where labor is scarce, high-priced, and often inefficient, and where materials are expensive and sometimes even impossible to procure. As a consequence of this condition, the repair of light structures, consisting, as it mainly does, of work either so small or so indefinite in extent as not to justify contracts, has, in the Eleventh Light-house District, and probably in most others, required the organization of a day-labor force and the provision of facilities for supplying materials from a central and economical market, in this case from Detroit, the headquarters of the district.

In the earlier years of the Light-House Establishment wood was often used for such structures as dwellings, beacons, foundation cribs, boat landings, and sidewalks, and, as many of these structures are now old, their repair has given rise to much annoying and expensive work. Even in the early days, all important light towers and many of the dwellings were, however, built of brick or stone masonry of excellent quality, and to-day an effort is being made to replace all permanently useful structures, originally built of perishable materials, with others which shall require little maintenance.

Wooden sidewalks seem scarcely worthy of extended notice, yet there were formerly so many of them in this district that, within the writer's knowledge, an entire cargo of lumber, weighing perhaps 350 tons and amounting to 280,000 feet, B. M., was each year needed for repairs. The tender belonging to the district is constantly busy, so that economy of her time is highly desirable. The increase in the cost of lumber and the steady decline in its quality also pointed to the desirability of making renewals with concrete.

Cement in bags is often spoiled in landing it at exposed localities; in barrels it is difficult to handle where wharves do not exist, and

even sand and gravel are expensive to supply at such localities. After all these difficulties have been overcome, it is found that concrete sidewalks constructed at the site, due to the high cost for labor (from \$2.50 to \$2.75, net, per day for common labor being the usual rate) and its relative inefficiency, have cost, at remote localities, between 25 and 30 cents per square foot. This is excessive, and on investigation it appeared advantageous to assemble the materials of construction at Detroit and to make the sidewalks there.

For the last two years sidewalk slabs have been made at the Detroit depot. Their dimensions are limited by the weights that can conveniently be unloaded by hand at exposed sites. About 400

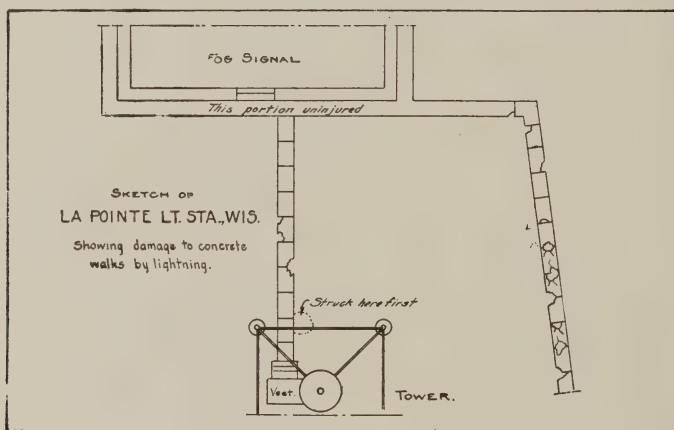


Fig. 1.

pounds seemed to be as much as could safely be handled. Another limiting condition, naturally, was that the slabs should be strong enough to bear the shocks of loading and unloading. The strains due to handling are, of course, insusceptible of calculation, but the conditions under which the slabs were to be transported and unloaded indicated 2.5 by 4 feet as the maximum superficial dimensions, and rough experiment proved that a thickness of 3.75 inches, properly reinforced, would be safe, the factor of safety being excessive to an unknown extent.

In fulfilment of these conditions, the first slabs were made in units from 1.5 to 2.5 feet by 4 feet by 3.75 inches. It will be noted the thickness, 3.75 inches, is less than that usual in sidewalk work, which runs as high as from 5 to 6 inches. To safeguard the slabs

against breakage in handling, they were reinforced with No. 10 gage expanded metal, 3 by 6 inch mesh, weighing 0.6533 pound per square foot and having an area of cross section of 0.1568 square inch per foot of width. Experience in 1908, on a rather limited output, showed that these slabs were unnecessarily thick, and beginning early in 1909, the thickness was first reduced to 3.25 inches, giving a slab weighing about 410 pounds, and then to 2.75 inches, with a weight of 350 pounds for slabs 2.5 feet wide.

As now organized, the party making slabs consists of five laborers at \$1.75 per day, one of whom, without extra compensation, acts as foreman. This party is employed at the Detroit depot, where, in a brick warehouse, fair facilities exist for the manufacture and tem-

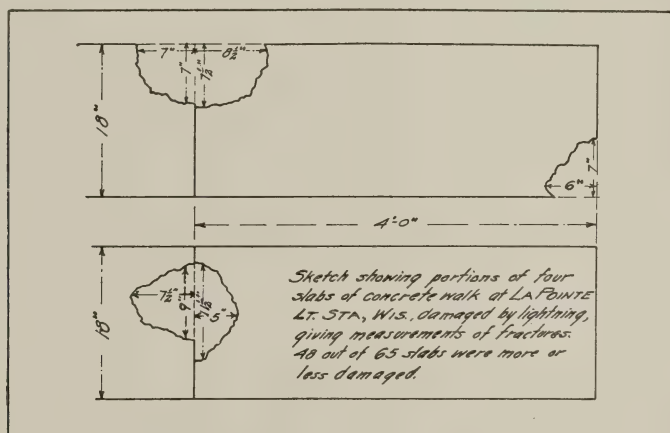


Fig. 2.

porary storage of slabs. It is supplied with seventy molds, of which fifty are 2.5 by 4 feet, and the remainder 1.5 by 4 feet. The concrete is made of cement, sand, and 1-inch gravel, in the proportions of 1 : 3 : 6, and for the 2.75-inch slabs is 2.25 inches thick, the remaining 0.5 inch of thickness being of 1 : 2 cement mortar. In making the slabs, all concrete and mortar are mixed in small batches by hand, a bag of cement making concrete for about 2.5 of the larger slabs. About 0.75 inch of concrete is placed in the mold and then a sheet of reinforced metal, 2 inches shorter and narrower than the slab, is placed upon this layer of concrete. The mold is then filled with concrete to within 0.5 inch of the top and the mortar finish immediately applied. After twenty-four hours, the side molds are stripped and the slab upon the base board moved by trolley to the

storage pile in the warehouse. After twenty-four hours' further setting, the slab is hard enough to be safely moved by hand truck to the outdoor storage piles. The party makes from twenty to twenty-five slabs per day.

Owing to the fact that indoor storage room is limited, and that operations are carried on through the winter, the labor cost, which includes that of handling each slab twice, is slightly increased over what it would be with ampler room. Recently, rib metal, No. 8 for 2.5-foot slabs and No. 7 for 1.5-foot slabs, has been adopted as reinforcement in place of the expanded metal originally used. In this rib metal the distribution of the metal is such as to secure greater transverse strength for the slab, and this should reduce the existing small loss from breakage in transit.

The cost of the slabs per square foot, based upon a thickness of 2.75 inches, is as follows, with cement at \$1.124 per barrel, sand and gravel at 90 cents per cubic yard, rib metal at \$0.02543 per square foot, and labor at \$1.75 per day of eight hours:

Cement	\$0.012
Sand	.0012
Gravel	.0048
Rib metal (average).....	.02543
Coal, oil, brooms, etc.....	.00054
Labor	.05645
Total	\$0.10042

This cost is derived from the experience of the past few months, during which time most of the slabs have been only 1.5 feet wide. As the narrow slabs call for practically the same amount of labor as the 2.5-foot slabs, the labor cost per square foot for the latter width is correspondingly less, probably not over 5 cents.

From January 1, 1909, to February 10, 1910, 5,079 slabs have been made, of which 2,433 are 2.5 feet wide and 2,646 are 1.5 feet wide.

The labor cost of moving slabs from the landing and laying them varies with the extent of fill needed. The following are average cases: At Isle Royale Light Station, on rocky and uneven ground, the cost of laying slabs bedded on gravel was 4.5 cents per square foot. At Mendota Light Station, on level, sandy ground, requiring little grading, the cost was 2.25 cents, and the same figure was reached at Charity Island. The most difficult case so far encountered was at Port Austin Reef Light Station, where an old brick

walk was removed, the new one laid on rough ground, and the total cost was 5 cents per square foot. The average cost is about 3.5 cents, making the total cost of the walk, exclusive of the services of the tender, about 14 cents per square foot. The slabs are easier to handle than the separate cement, sand, and gravel, so that probably less of the cost of the tender is fairly chargeable against the slab walks than against walks built in place. The saving due to the use of slabs is certainly not less than 10 cents per square foot, or a total of \$4,026 on 40,260 square feet made since January, 1909.



Fig. 3. Showing effect of lightning on reinforced concrete sidewalk.

At La Pointe Light Station, Wis., the main light and the fog signal are three-fourths of a mile east of the keepers' dwellings, which are nearly the same distance east from the light and mechanically operated bell on Chequamegon Point. As one set of keepers operate both lights and both fog signals, it is necessary to maintain nearly a mile and one-fourth of walk, and recently the old wooden walk has been in part replaced by laying slabs from each end toward the dwellings. At the easterly or main light, sixty-five 1.5 by 4 foot slabs were laid in the fall of 1908. The alignment of the walk is shown on the accompanying sketch, and it should be stated that the irregularly shaped slab at the angle was molded in place without

reinforcement. The main light tower is a skeleton, pyramidal structure, with main legs of cast iron, braces of wrought iron, and a central cast-iron stair cylinder, surmounted by a cast-iron lantern. The tower legs and the stair cylinder are anchored by the usual bolts set in concrete footings, and in May, 1909, had no lightning rod, the ball on the top being surmounted by a pinnacle with platinum tip.

On the night of May 7, 1909, during a severe thunderstorm, the keeper observed an unusually vivid flash, and immediately thereafter

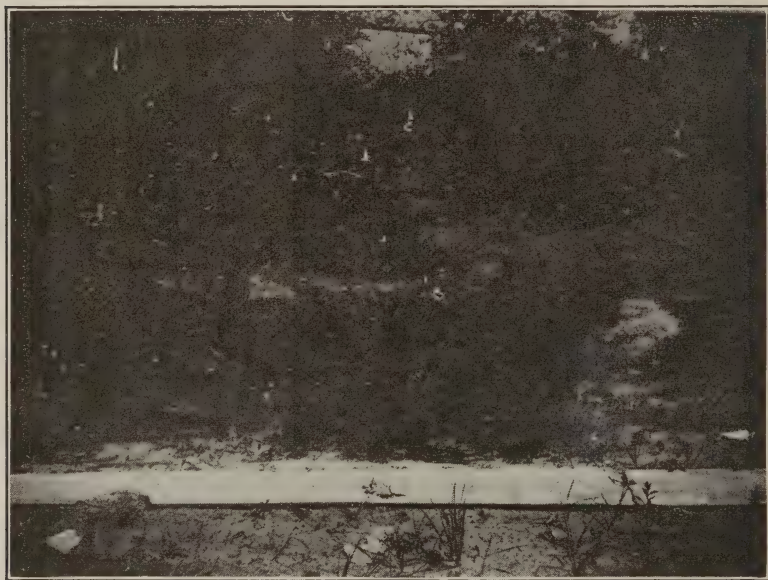


Fig. 4. Showing effect of lightning on reinforced concrete sidewalk.

a thunder clap, which seemed close at hand. Immediately thereafter the main light was seen to have been extinguished. On his way to relight the lamp, the keeper noticed that the corners of the slabs were broken, and pieces of concrete scattered on the snow alongside the walk. On reaching the lantern, it was found that no damage had been done to the lens or lamp. It subsequently developed that the tower had been struck by a bolt, which fused the platinum tip of the pinnacle and jumped from the lowest horizontal brace to the ground east of the entrance, where a hole nearly 2 feet deep and wide was made. The same charge then followed the walk, breaking two slabs near the entrance and doing little further damage until it

passed the second angle; thereafter, nearly every slab was more or less damaged, the breaks being at the corners or along the ends. Although the slabs on both sides of it were slightly broken, the unreinforced slab was not injured. The severest damage occurred in a portion of the walk about 60 feet long, which was covered by from 16 to 18 inches of snow. Fig. 1 shows a number of the breaks, to scale, and Fig. 2 gives typical dimensions of some of them. Of a total of sixty-five slabs, forty-eight were more or less injured. Due to the presence of the reinforcing metal, the repairs will be easy.

From the appearance of the walk four months after, it seems that, in the equalization of electrical potential, a part at least of the charge followed, with the usual disruptive violence, along the reinforcing metal of the walk, which was almost, if not quite, electrically continuous, due to the presence of moisture in the joints between slabs, and that disruption occurred only where continuity was interrupted, as where dry snow covered the walk or where there was partial air, or other non-conducting, space between slabs.

Towers of this type have not usually been protected by lightning rods, but that at La Pointe and others like it are hereafter to be protected by two lightning conductors made of flat copper ribband, two by one-eighth inches in cross section, the upper end of each being slipped over an anchor bolt and held in place by the nut, the lower 10 to 15 feet being buried in moist sand. These conductors, if properly maintained, may assist in guarding against occurrences like that herein described. During the past season, three other towers, all of masonry, were struck by lightning, and in each case more or less efficient lightning rods were in place. One of the towers struck was provided with two rods. This unusual grouping of casualties due to lightning has led to investigation of all protective apparatus in the district, and some of it has been found to be of rather doubtful efficiency, due entirely to deterioration since its original installation.

HYDRO-ELECTRIC DEVELOPMENTS AND HIGH TENSION PRACTICE*

BY

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(Continued from the July-September number of PROFESSIONAL MEMOIRS)

Line.—By far the most important element of the system to the engineer designing the plant, as distinguished from the manufacturing designer, is the line. The generators, switchboards, and transformers present many and very serious problems, in some cases difficult of solution, but they are almost wholly within the natural province of the maker's designer, and, while the engineer of the system should understand and follow to some extent the questions thus involved, it is usually better to leave the design of the actual apparatus to the manufacturer, protecting the interests of the owner of the system by proper guarantees and tests.

The governing factors of the line layout are: First, economy of transmission; and, second, regulation. The first affects the actual cost of producing and delivering the power, while the latter affects only the acceptability of its form, which is quite as important as the former. In other words, power delivered at an unsteady and varying voltage is very unsuitable for most work and is not permissible commercially.

Economy.—Here, the value of the power lost in the line must be considered against both the cost of the construction and the cost of operation, to which must be added the interest, depreciation, and maintenance charges.

Since the transmission distance is fixed and the nature of the country to be traversed is determined, the chief factors that can, as a matter of practical design, be varied to change the cost or economy of the line are the voltage and the amount of copper used. The line may be said to be economically designed when, at the highest voltage that is found to be desirable, any increase in the

*Lecture delivered at the United States Engineer School, February 26, 1909.

amount of the copper proposed would entail a greater increase in interest charges than the power saved by virtue of the decreased loss would net. And, at the same time, any decrease in the amount of copper would decrease the cost of interest less than the increased loss of power would cut down the revenue. The line must at the same time be capable of supplying good regulation. As a matter of practical design, it is well to use a somewhat less amount of copper than the most economical design would seem to require. The amount of copper will often be rather determined by the regulation of the line than by its absolute efficiency.

To determine the line, electrically speaking, it is necessary to select the frequency, the voltage, and the size of the conductors.

Frequency.—In the United States the frequency will be either 60 or 25 cycles, leaving out of account the matter of 15-cycle railroad work. In any given case, the best frequency will usually be clear. In most plants for a miscellaneous service, including a good proportion of lighting or small motors, 60 cycles will be the best suited; for 25-cycle are lamps, except outdoor types fed through mercury rectifiers, will be nearly out of the question without some frequency changer, and incandescent lighting on 25 cycles is not at all desirable. On the other hand, where there are many large motors to be supplied and, generally, where large blocks of power must be handled at relatively low voltage, 25 cycles is very much to be preferred. Such plants as the Niagara Falls developments require 25 cycles, while many or most of the Southern hydro-electric systems now supplying or planning to supply power to the cotton mills of this region, or light and miscellaneous power to the several tributary communities, are 60-cycle plants. The fact that a plant must supply power to a number of existing 60-cycle plants is sometimes a determining factor in the choice of frequency.

Voltage.—Generally speaking, in a system in which any even moderate amount of power is to be transmitted a considerable distance, the voltage should be as high as can be economically and safely handled. The limitations are found: First, in the insulation of the line; second, in the cost of insulators and line construction; and, third, in the mechanical size of conductors.

With careful construction and good quality of material, 60,000 volts is a satisfactory workable voltage. I do not mean to say that this potential does not require careful expert handling, for it does, but that when so handled it is thoroughly practicable commercially. Voltages up to 80,000 and 100,000 are now being used, but

these require rather extraordinary precautions and are not yet well tried out.

Beyond a certain limit, the increased cost of insulators and apparatus due to the higher voltage gets to be more important than the saving in power. This condition is ordinarily met only in short-distance work and with rather small powers.

For mechanical reasons, nothing smaller than about a No. 4 or 5 wire is suitable for main transmission lines. Smaller wires may be used on short branch lines, however.

Size of Conductor.—The size of conductor is, of course, determined by the considerations of economy already discussed.

Calculations.—In determining the line characteristics the matter of calculations becomes of importance, and should be rather carefully discussed. The results usually desired are: The voltage drop and the energy loss in the line, with a given load delivered at the receiving end, with a known power factor, and, further, the output and power factor of the generator corresponding thereto.

With low voltage and short distance of transmission and especially with low frequency, the charging current of the line is not an important matter and may be neglected in the line calculations. In this case the drop may be obtained as follows: Resolve the line voltage into two components, one in phase with the current, the other at right angles thereto. Add to the energy component the product of the current by the resistance of the line, and add to the lagging component the product of the current by the line inductance or reactance. The two original components thus increased are the components of the generator electro-motive force. The resultant value of the generator electro-motive force is the square root of the sum of the squares of the two components. The power factor at the generator is the energy component divided by the resultant voltage. The true loss in the line is the square of the current times the ohmic resistance of the line. The drop in the line is the generator voltage less the delivered voltage.

For example, we may assume the transmission at 25 cycles of 5,000 kilowatts at 25,000 volts for twenty miles, being about the condition of the Niagara-Buffalo transmission. Assume, further, that the resistance of the conductor is .32 ohm per loop mile (two No. 000 wires) and its reactance per loop mile is .54 ohm, and that the power factor of the load is 80 per cent. The energy component of the voltage will then be $25,000 \times .80 = 20,000$ volts, and

the current is $\frac{5,000}{25 \times .80} = 250$ amperes. The inductive component of the voltage is $25,000 \times .60 = 15,000$ volts. It equals, also, $20,000 \tan \cos^{-1}.80 = 15,000$ volts. The ohmic drop $= 250 \times 20$ (miles) $\times .32 = 1,600$ volts, and the inductive drop $= 250 \times 20$ (miles) $\times .54 = 2,700$ volts. The spacing of the wires is here taken at 4 feet, a fair figure. The components of the generator electromotive force are thus $20,000 + 1,600 = 21,600$, and $15,000 + 2,700 = 17,700$, and the resultant value $= 28,000$ volts, since $21,600 \cos \tan^{-1} \frac{17,700}{21,600} = 28,000$. The power factor is $\cos^{-1} \frac{17,700}{21,600} = .77$, and the drop is $28,000 - 25,000 = 3,000$ volts $= 11$ per cent. The true line loss is $250^2 \times .32 \times 20 = 400$ kilowatts $= 8$ per cent. In this case, the charging current is 20 (miles) $\times 25,000 \times 2\pi \times 25 \times .0087 \times 10^{-6} = .7$ ampere where the capacity per mile is .0087 microfarad. This is evidently entirely negligible.

But, in most cases of transmission to a considerable distance, the charging current will be a more or less important item and may be altogether too large to neglect in its effect on line drop and the other factors. Strictly speaking, the capacity and inductance and resistance being uniformly distributed along the line, the usual formulæ are not accurate as they relate to capacity, etc., located at definite points. But for all but the most extensive plants such an approximation is sufficiently accurate. The method given below may give an error of some few per cent in several hundred miles of transmission. The approximation recommended here is the assumption that one-half of the capacity is located at one end of the line and that the other half is located at the other end. It is then easy to calculate the line quantities, somewhat as before. In this case, having given the power delivered and its power factor, the delivered voltage and the line constants, resolve the current into components in phase with and at right angles to the voltage. The lagging component of the load will then be exactly opposite in direction, and in phase with the charging current to the condenser representing half of the line capacity at the receiving end. This charging current should thus be subtracted from the lagging component of the load, and the line current at the receiving end will be the square root of the sum of the squares of the components thus obtained, or, in other words, will be the power component divided by the $\cos \tan^{-1} \frac{\text{inductive component,}}{\text{power component}}$ and the power factor will

be this cosine. With this fresh value of the load current, which includes the half capacity at the receiving end, the calculations of the generator voltage and the true loss are made in the same way as before. But, since there remains the other half of the line capacity, connected at the generator end the generator power factor and generator current are not yet determined. To obtain these, resolve the line current at the generator end into two components, one in phase with the line voltage and the other at right angles, then subtract from the inductive component of the line current the charging current of the capacity assumed connected at the generator end of the line. This, with the in-phase component, will then give the two components of the actual generator current and the true power factor, as already explained. Instead of using the square root of the sum of the squares of the components to get the resultant, I usually find it more convenient to use the trigonometrical form which I have illustrated above.

The values of line capacity and inductance and resistance are most easily taken from tables, as found in hand books, but the capacity and inductance may be calculated from formulæ if desired. The capacity in microfarads of a mile of two parallel wires

of radius r , and with distance between centers D , is $\frac{.0193}{\log_{10} \frac{D}{r}}$. And

for the same two wires the inductance in henrys is $.001484 \log_{10} \frac{D}{r}$ approximately.

As an example of the application of the last method of line calculation, assume a line 150 miles long of No. 000 wire spaced 7 feet and transmitting 5,000 kilowatts at a power factor of 85 per cent and a voltage of 80,000 volts and 60 cycles. Then,

Length	miles..	150
Voltage delivered.....	volts..	80,000
Power delivered.....	kilowatts..	5,000
Spacing of wires.....	feet..	7
Size wire.....	No..	000
Frequency	cycles..	60
Capacity for 150 miles.....	farads..	112.5×10^{-6}
Charging current load end condenser.....	amperes..	16.8
Charging current generator end condenser....	amperes..	18.4
Total ohmic resistance.....	ohms..	95
Total inductive resistance.....	ohms..	228
Delivered current = $\frac{5,000}{80 \times .85}$	amperes..	73.6

	<i>Ohmic</i>	<i>Inductive</i>
Components of load current.....	62.5	40
Charging current		17
Components of line current.....	62.5	23
Line current		66.3
Components of line voltage.....	75,000	26,000
Ohmic and inductive electro-motive forces.....	6,250	15,100
Components of generator voltage.....	81,250	41,100
Generator voltage.....	91,600	
Line drop=91,600—80,000=11,600=12½ per cent.		
Components of line current	59	30
Charging current		18
Components of generator current.....	59	12
Generator current	60.25	
Power factor	.80	
Line energy loss $66.3^2 \times 95 = 416$ kilowatts.		

If this calculation had been made neglecting the capacity of the line, the generator voltage would have been 95,000, its power factor .79, and the drop 16 per cent, and the energy line loss 510 kilowatts, showing the importance of capacity in this case, and, further, the improvement both of the drop and the energy line loss, as well as the saving in generator capacity due to the line charging current.

So far the calculations have been assumed to be for single-phase circuits, while in practice systems are always three-phase. A good rule to follow in making the calculation for three-phase is to calculate the circuit as though it were single-phase and carried one-half the actual power at the same power factor; for the percentage line drop and the percentage energy loss of a three-phase line are the same as the same percentage quantities in a single-phase line transmitting half the power over two wires having the same spacing and the same size as any two of the three wires. The three-phase line is assumed to transmit over three wires at the apexes of an equilateral triangle. The drop will not be very different, but a little higher with the three wires of the three-phase system arranged on one crossarm at the same height from the ground.

In laying out an actual line it is usually the best plan to assume some voltage and size of wire and make the calculations of the various quantities of importance, and then to determine how the conditions can be improved by changing some of the assumptions. There are so many factors influencing the general final choice that

it is not worth while to try to determine the line for one condition only, as, for instance, drop, before considering all the others.

Following the determination of the size of the conductors comes, perhaps, the general layout of the system.

This layout must depend almost entirely on the conditions of the case, but there are some general guiding principles that may be outlined.

In practically all cases duplicate lines are provided, so that service need not entirely be interrupted in case of failure of a line. It is not always the practice, however, to provide double the full load capacity in lines. It is assumed that in case of emergency some load can be dropped without great loss, and that the line drop at times of emergencies may be allowed to be considerably greater than normal. Thus, the essential thing is two separate structures, so that one is not crippled by the mechanical injury of the other, rather than the providing of absolutely duplicate carrying capacity.

The cost of the extra line is, of course, very considerable, and should be kept down where possible. The cost in interest of the extra capital required must be compared to the cost in money loss and loss of the public confidence resulting from a long shut down. As a compromise, it is common to build two lines on one set of towers, where steel type of construction is used. The theory here is that the towers will be so well put up that they are reliable and that the duplicate lines will care for all the common troubles of broken insulators, burned-off or defective wires, etc. This reasoning is often quite sound. The limitations introduced by having too little capacity for transmitting the whole power over one circuit, when the other is out of commission, may be largely eliminated by having a change-over or paralleling switch at one or two points in the line, thus sectionalizing it so that one portion only of the bad line need be out—that is, that part in which the failure has actually occurred. The two lines can then be paralleled as usual on all the other portions. In large systems it will be well to have a third or a fourth line and, furthermore, it is very desirable from many points of view to have two separate routes to the distributing center, so that such accidents as floods and landslides can not cut out the service entirely. Often such double routing will permit the picking up of valuable additional load and the utilization of other water powers. This arrangement constitutes in one sense a closed ring, and any particular point can be reached from

either direction, so, in case of disturbance, there will always be a second feeding route.

Actual cases vary so greatly in their conditions that the layouts of different plants will be very different. Each situation must be studied to get a minimum of cost with a maximum of flexibility.

Spacing of Wires.—The distance by which the high-tension wires shall be spaced is an item of considerable importance. The only reasons for a wide spreading are electrical; that an arc once formed between two transmission wires shall not hold too easily



Fig. 5. Wooden pole lines, new style on left; working transmission, 44,000 volts.

and that wires shall not be easily short-circuited mechanically by bits of wire or branches of trees and such things. There is much more trouble on this score than would be imagined on a line, say, with 5-foot spacing of wires. It is in some places a favorite pastime of boys and others to throw short pieces of wire over the line and see the flashes. On a high-tension line this is a very troublesome thing, as the high-tension current is not usually of a sufficiently high value to burn off the wires quickly. Again, limbs of trees are sometimes carried some distance and dropped upon a line, resting on two wires; this may or may not shut down the line. In the West, birds with a long spread of wings and long legs frequently short-circuit the lower voltage lines, 30,000 or 40,000 volts,

by trying to fly through. The Niagara Falls Power Company was in the early days shut down at least twice by cats getting into the high-tension circuits. Evidently, the farther apart the wires are the less the danger of a short circuit. A normal voltage of 100,000 volts will only jump about 10 inches.

It is, of course, customary to grade the spacing more or less, according to the line voltage, from 2 or 3 feet on 10,000 or 15,000 volts up to 6 or 7 feet on 60,000, and greater distances on higher voltages. The larger spacing, of course, requires a somewhat stronger structure and a wider right of way for the line. This latter point is not of much consequence in the Western waste country, but may be in more closely settled places.

Capacity is greater and inductance less as the distance between wires is lessened. The charge with the usual range of spacing is not very important.

In addition to the line considerations so far discussed, there are many others of a general nature that are still of interest and importance.

The attempt has frequently been made to devise automatic arrangements to cut out one of two parallel lines when a breakdown occurs, without shutting down or even momentarily interrupting service on the other line, but so far these have met with little success. When a short circuit occurs on one of two such lines, it is evident that current flows into the injured line from the generator in considerable volume and that, also, energy will flow into the bad line from the farther end, since the lines must be paralleled at both ends to divide the current. The current that flows into the far end of the bad line must come from the generator and so must go out on the good line, so that at the generator both lines seem to be short-circuited, and it is not possible to tell directly on which one the trouble actually occurred. But at the farther end the energy is flowing backward in the bad line and outward in the good line, so that, theoretically, if a circuit-breaker relay be used on the far end which will operate on reversed flow of energy, but not on even a heavy direct flow of energy, such an arrangement will cut out the bad line at the far end and not disturb the good line, so that then the current will cease to flow into the good line at the generator end, at least in short-circuit quantities, so that there will then be no tendency to operate an overload circuit-breaker in the good line at the generator end and yet such an overload instrument will, of course, open the bad line. Thus, if the action of the overload



Fig. 6. Testing insulators of Fig. 7 under 200,000 volts; rain test..

breakers at the generator end is made so sluggish that they will not act until after the reverse energy breakers at the receiving end have acted, the bad line will be disconnected without disturbing the good line. This arrangement is theoretically correct and will operate well under favorable conditions, but as an actual matter of experience is very unsatisfactory. The difficulty lies largely in the reverse energy relay, which fails to act when the short-circuit current has a low power factor, as it usually has, and when the line voltage drops low, as it often does, so that the arrangement is seldom used and is not generally to be recommended. It may be said, however, that it is entirely possible that improvements may be introduced that will make the system a success.

Grounds on long high-tension lines will usually set up severe disturbances in any wires within a considerable distance of the high-tension line and parallel thereto for a considerable number of miles. Such are telephone or telegraph lines, and the disturbances may be sufficiently severe to not only interrupt their operation, but sometimes to cause fire. This disturbance is sometimes due to static induction, for the grounding of one wire of the three of a three-phase system will unbalance the system in its inductive effect on neighboring conductors in such a way that a resultant alternating potential will be induced on them. The disturbance, on the other hand, is sometimes due to electro-magnetic induction from the short-circuit current which flows in the long loop, one way in the wire and the other way in the ground. This must evidently set up lines of force which cut the neighboring wires, and if they are parallel for a long distance and the short-circuit current is of sufficient magnitude this induced electro-motive force will be several hundred volts. This is an exceedingly hard matter to control and is at the present time in a very unsatisfactory state. It is, of course, desirable to avoid as far as possible such unbalanced conditions and this is otherwise necessary, ordinarily, for the general benefit of the plant's operation.

Operation.—The operation of a large hydro-electric system requires a high degree of organization and discipline. It is necessary to keep continuity of service at all hazards, and to do this it is necessary to act with great promptness and sureness at times of accident, and each operator must not only know just what his responsibility is, but he must know what to do and be able to think quickly without being flustered. When there are several stations in parallel and a number of pieces of apparatus that must be syn-

chronized or otherwise related to one another in different stations, it is necessary for each station man to know his duty with regard to all the others, and, further, it is necessary to be able to communicate between stations. Private telephone systems are, of course, usually installed along the pole line, but these are usually

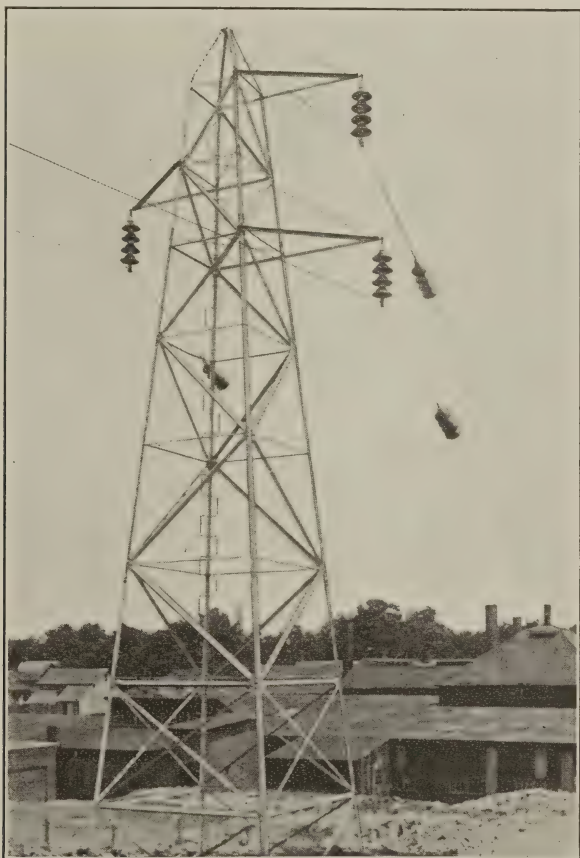


Fig. 7. Steel tower, with suspension insulators and strain insulators; 115,000 volts.

made unusable by the static or electro-dynamic induction at the time of disturbance, so that they are unreliable just at the time that they are the most needed. So far, it is hardly possible to maintain communication over such a telephone line when there is an unbalanced condition on the high-tension line. If the bad line is out entirely, the operation of the telephone is all right.

It is necessary to carefully protect the men using these telephones, as the induced voltage may easily be dangerous.

It is peculiarly true in the operation of electrical systems that "an ounce of prevention is worth a pound of cure" on account of the very extensive damage usually following a small break. For this reason it is usual to carefully and periodically inspect all lines and apparatus. Trouble can often be thus avoided, if the initial weakness be detected before the final break.

Line Construction.—When the line is actually determined upon as to its electrical characteristics, the problem of mechanical line structure next comes up. This is one of the most important in the whole design, for here lies the greatest cost oftentimes, and the greatest danger to the operation of the system.

Shall wooden poles or steel towers be used?

This is a complex question; each type of pole is suited to certain conditions which are, usually, not so well suited to the other type.

Wooden poles where obtainable at all, are relatively cheap, easily secured and transported and handled by labor such as can be obtained anywhere; they can be readily erected, and in climates where they do not rot quickly are fairly reliable and have a reasonable life. Good wooden poles, however, are very hard to get at the present time in most parts of this country, can not usually be obtained in large enough sizes for heavy work and are very far from uniform, either as between individual poles or in different parts of the same pole.

Wooden poles are suited to relatively dry climates, near where the timber actually grows, where transportation of steel is expensive and for small and less important or for temporary lines.

It is probable that much can be accomplished to lengthen their life by treating poles with creosote or other suitable material to prevent rot. The United States Government has done a good deal of investigating in this direction, which I am inclined to believe will be of much service in the future and is not at the present time sufficiently appreciated by electrical engineers.

Wooden poles have a certain advantage over steel, namely, the fact that the wood of the pole and the crossarm, if this is made of wood, though inferior and unreliable for regular reliance as insulation, are still a very great help in times of emergency, when an insulator breaks down or lightning jumps over it. The wooden poles have a corresponding disadvantage, however, for wooden poles will char when current leaks over them. This will sometimes happen

with wet or dirty insulators, especially in the vicinity of the sea-shore, as in the neighborhood of San Francisco, where the dust

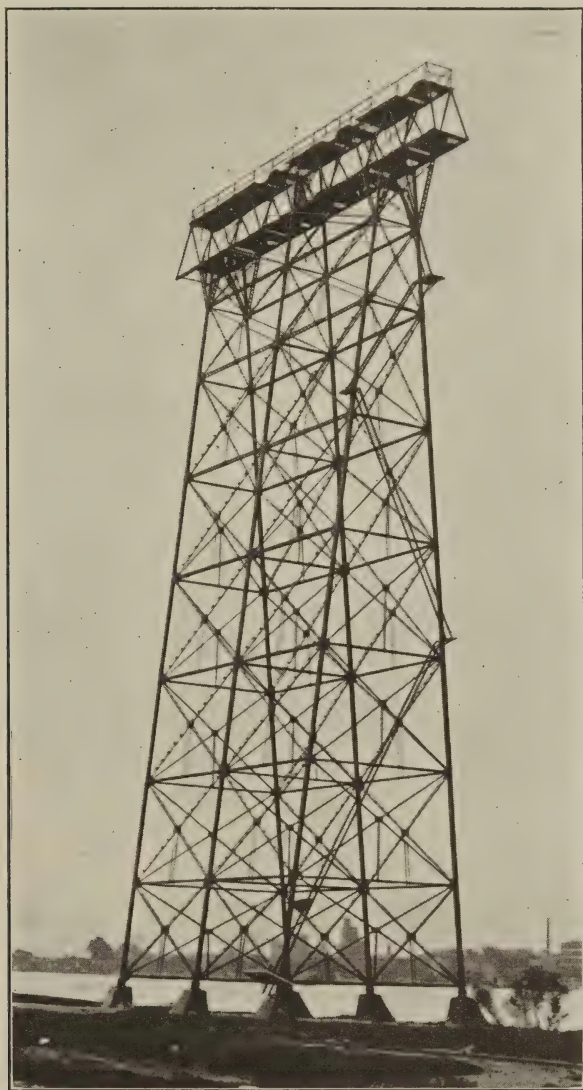


Fig. 8. Special tower for river crossing. Canadian Niagara Falls Power Co.

that blows from the ground is somewhat alkaline and causes a sort of partially conducting coating to form on the surface of insulators. A wooden pole, once well afire or aglow at some one point, will con-

tinue to burn for days in dry climates, slowly perhaps, spreading and finally being eaten off without any actual blaze appearing.

On the other hand steel poles or towers, as they are usually constructed, have quite the contrary characteristics. They are costly, but very reliable and permanent if properly designed and protected. They must, however, be designed by some competent structural iron designer, be then constructed at some suitable shop, which may not be found at all points, and, finally, must usually be shipped for a considerable distance and often must be erected by more or less skilled men. These conditions go far to neutralize the advantages of towers, where they can be dispensed with. It is the custom, however, for most eastern designed plants to use steel towers.

But with the steel line, the extra cost and extra strength of the towers means that they must be put as far apart as possible. The length of span is limited chiefly by the strength of the conductor, for if the span be too long the wires will break when they are loaded with ice, as in a sleet storm, especially if the wind be blowing.

Towers.—The strength of the towers must usually be determined by the builder. It is the function of the transmission line engineer to specify the strains the towers are to resist and, perhaps, to choose the type of tower he prefers from a number offered him by the steel designers and, usually, to enforce these conditions with actual tests. It is not ordinarily his proper function, however, to design the details of the steel work of a transmission tower.

To determine the strains on a line conductor stretched between two pins, it is customary to assume that it falls in such a curve as to be a parabola. In this case, the formulæ giving the strain and length will be

$$T = \frac{y^2 w}{8x}$$

$$l = y + \frac{8}{3} \left(\frac{x}{y} \right)^2$$

where y = length of span in feet;

w = weight of conductor per foot;

T = tension in conductor;

x = sag in feet;

l = length of conductor in feet.

It should be understood that the curve actually taken by the wire is not a parabola, but a catenary. These two curves are very

closely alike in form for tightly stretched wires, such as are used in transmission lines, the maximum error in ordinary cases being somewhat less than 1 per cent and in such a direction as to make the true strain somewhat less than that given by the parabola formula.

It will be seen from the formula that the strain is inversely proportional to the sag for the same spacing of poles. Also, that the strain is proportional to the span with the same percentage of sag. The *weight per foot* of the formula is to be the weight of the wire, when there is no ice or wind, but the possibility of the accumulation of a thick ice layer or a high wind makes it necessary to proportion the strength for these very much more severe conditions. For determining an actual span, it is often assumed that there will exist a layer of ice one-half inch thick all around the wire and the strain then calculated with the assumption that there is a wind blowing of some forty miles an hour. Many engineers do not consider this a severe enough assumption for most localities and, in my opinion, it is not *for important main lines*.

In calculations, the weight of the ice must be added to that of the wire to get the weight per foot, and the whole applied in the same formula as before. This gives the strain without wind. The effect of the wind is to add a strain at right angles to the weight that is approximately horizontal. Wind pressure may be obtained from a table or a formula. There are many given: for example, $T = .004 V^2$ where T is pounds per square foot and V is velocity of wind in miles per hour. It may roughly be assumed that the wind pressure will be about 20 pounds on a square foot of flat surface with the wind at 70 miles an hour. Further, the pressure depends on the square of the velocity, approximately. If the surface is cylindrical, like a wire, the pressure will not be much over half, say .6 of that given.

Thus, to get the total strain on the wire with the wind and ice, the weight of wire should be added to the weight of ice and the wind pressure combined at right angles—that is, by taking the square root of the sum of the squares of the two quantities. This resultant may then be substituted in the parabola formula.

It is customary to allow a factor of safety of from two to three in the strength of the conductor where this is the limiting factor, but, in any case, to keep the strain within the elastic limit of the material which, in line copper or aluminum, is usually about half the ultimate tensile strength.

With steel towers ordinary spans in important lines run from 400 to 800 feet, but special spans are made much larger. Fifteen hundred feet is not uncommon, and a span of 2,300 feet has been in operation several years near San Francisco.

But there is a great difficulty introduced into the computations of span strains by the effect of temperature. The sag of a tight wire is very sensitive to the actual length of wire and, consequently, the strain will be much influenced by small changes of length. The range of temperature between summer and winter is great enough to very materially affect the strains. The safest method is to calculate the strain and install the wires for the coldest temperature to be expected, and then any higher temperature will simply lessen the strain. It will, however, increase the sag and bring the wire nearer the ground. The calculation of the change in sag will be made by an approximation, calculating the length of the wire hot as compared with its length cold by the usual formula for temperature expansion. When the new sag has been roughly calculated for a new temperature, another correction must be made for the difference in the stretch of the wire due to the change in the purely mechanical strain. This calculation is thus quite complicated, and, although it is possible mathematically to combine some of these formulæ to simplify the computations, it is not possible to discuss the matter further here.

The expansion coefficient .0000096 per degree Fahrenheit for copper may be used, .0000064 for iron and .0000128 for aluminum. It is thus seen that the aluminum is more readily expanded and has here a disadvantage. Its lesser tensile strength is offset by its light weight.

In running high-tension wires, it is necessary to take account of the atmospheric temperature at the time of stringing or the sags will not be right, and may happen to be too great when the strain of extra cold weather comes. When the elastic limit of the wire is exceeded in any of the severe conditions it will not necessarily break, for a slight stretch will relieve much of the strain. Any such stretch will, however, develop any weak spots and will be permanent and cause thereafter a greater sag than before.

The choice between aluminum and copper for line wires is not always easy to make. Either material is now satisfactory in performance. Aluminum has an ultimate tensile strength, when hard drawn, of, perhaps, 2,500 pounds per square inch, while hard-drawn copper may be as high as 60,000 pounds. On the other

hand, the weight of aluminum is so much less that the section of a conductor can be made 60 per cent greater, so as to give conductivity as great as that of copper, and it will then have only one-half the weight of the copper, while the tensile strength of the larger aluminum section will be about five-eighths that of the copper, so that the two are on a par in this matter.

The aluminum will have a little larger electrostatic capacity on account of its greater diameter (1.27), but the difference is small.

The joints in aluminum are made by mechanically clamping in some form, as it does not solder well. This is usually accomplished by slipping a long double tube, wrapped up, of thin sheet aluminum over the two ends to be joined, laid side by side and violently twisting one end of the overlap while holding the other. This joint, called the McIntire joint, has been very satisfactory and shows a low resistance.

Both aluminum and copper should be used in cables, not solid wire.

It is clear that for equal conductivity an aluminum conductor has about half the weight of a copper conductor, hence the price per pound may be about twice that of copper before its cost is the greater. The choice is governed somewhat by matters of convenience: freight, size of conductors, and such other considerations.

To return to the poles or towers. In specifying the tower strengths it is customary to assume that they must stand (1) on each pin support, and, as a whole, the strain produced with a maximum of ice on all conductors by the maximum wind across the line, (2) the strains brought by a breaking of one or more of the conductors on one side of the tower as might be brought about by an arc. This may bring both tensional and torsional strains on the tower and local strains within the structure.

Again, not only must the tower be strong, but it must not overturn under these tests. This requires deep or heavy foundations or guying.

Lightning Protection.—The insulation of the apparatus and the line is one of the limiting conditions. The station apparatus must be designed safe by the manufacturer. The proper design of the line falls on the transmission engineer. First, he must meet normal voltages and normal variations thereof, say, rises to double voltage caused by ordinary operations of switching, etc. This is not very difficult for the line structure. The quality of porcelain is such that it does not deteriorate under strain nor particularly

with time, and so a well-insulated line insulator will stand up indefinitely if not mechanically injured. But, at infrequent intervals, there occur abnormally high electric strains, as from lightning. Such strains, in extreme cases, are so high as to be nearly irresistible, but, fortunately, are very local in their attack on the line. The result is usually a spillover of high-tension current to earth at or near the point struck, and often the following after of the current from the potential of the generator. This will usually cause a shut-down or other form of trouble, and perhaps the injury of actual apparatus. This condition is a very hard one to meet, since lightning may come at any point and is, ordinarily, much above the power of any insulator to withstand. With steel towers and steel pins, the slightest spit of current over an insulator is practically equivalent to a dead ground, nearly; so that this construction is much more severe on systems than the wooden pole type.

The best available means for protecting the line itself against lightning disturbances is the installation of a ground wire, or, better, two or three ground wires, over the transmission wires, well spaced and insulated from the latter so that the ground wires may intercept discharges as they come from the air and carry them to earth. Such ground wires should be grounded at every pole and be very securely installed, as a ground wire falling would be almost sure to shut down the plant. This result happened so often when grounded wires were first used that many plants which had installed them took them off again. This trouble was due to poor mechanical construction rather than to any mistake of principle.

In addition to the ground wires to protect the line, the best and most free discharging arresters must be used to protect the apparatus at the stations. This apparatus is very sensitive and must have every advantage of protective devices. It is not possible here to go into a consideration of the various types of lightning arresters proper. It may, however, be said that the line problem is a very different one from the station problem, for the former must meet the very severe direct discharge, while the station receives only the wave of electricity which does not spill over to ground at the point of attack, and which has proceeded along the line to the station. The latter is evidently much less severe. On the other hand the apparatus at the station is much more sensitive than the line insulators.

The more important features of the system, both hydraulic and

electrical, have now been touched upon as far as time would permit. But on such a vast subject the treatment must of necessity be general and hasty. There are, in addition to these strictly engineering matters, other very important considerations concerning operation, dealing with customers, financing, developing load, and such, but these fall outside the scope of the present lecture.

ROCK EXCAVATION AT ROCK RIVER POOL*

BY

LIEUT. J. M. WRIGHT

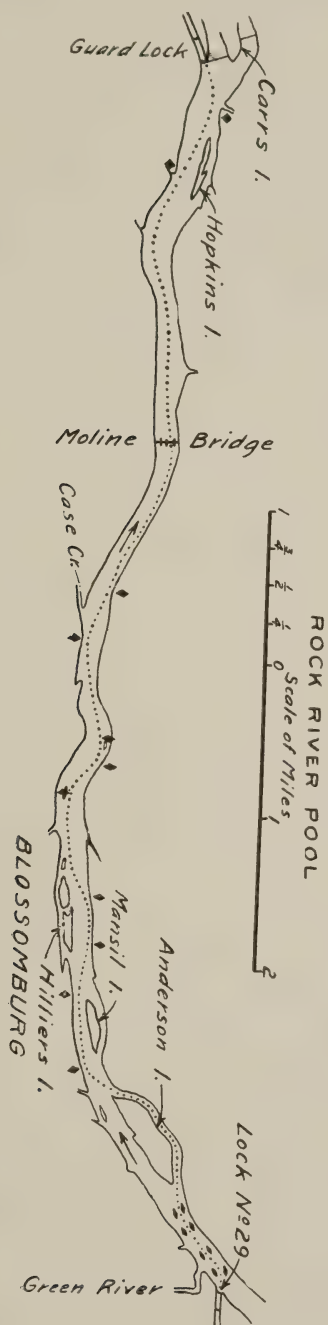
Corps of Engineers

Rock River Pool extends from the vicinity of Lock No. 29 of the Illinois and Mississippi Canal to Lock No. 35 of that canal, its total length being about 8½ miles. It was formed originally by dams across the two branches of Rock River at the head of Carrs Island, opposite Lock No. 35. These dams were crib dams, in the first place, but are now of concrete, the north branch dam, however, having been moved down to the turnpike bridge across Rock River. The new dams were built at private expense for waterpower purposes, and the old ones have been only partially removed.

The Illinois and Mississippi Canal was constructed with a depth of 7 feet. Consequently, it was desirable to have a channel of that depth through Rock River Pool, which serves as a link joining the Western and the Milan sections of the canal. It was found, however, that about 3.5 miles of the 8.5 miles of slack water in the pool had an available depth of less than 7 feet. The desired 7-foot channel could be obtained in two ways, either by dredging operations in the pool, or by raising the dams at Carrs Island until the necessary depth was obtained. The latter solution of the problem had to be rejected on account of the large amount of low-lying ground close to the river, which would be overflowed. It was found to be impossible to purchase this land under anything like reasonable terms, and to go ahead with the project without such purchase would have brought on many troublesome damage suits. It was therefore considered better to get the needed depth by dredging and excavation of rock and fire-clay bottom.

In 1909, *Drillboat No. 6* and the dipper dredge *Ajax* commenced work about the 1st of April at Hilliers Crossing. The drillboat, which during the fall of 1908 had nearly completed the work neces-

*A report submitted to Maj. C. S. Riché, Corps of Engineers, in November, 1909. (See PROFESSIONAL MEMOIRS, No. 6, page 259.)



sary at this place, worked at Hilliers for about ten days, and was then transferred to the vicinity of Lock No. 29. The dredge was employed in that neighborhood for over a month, and was then moved to Lock No. 29. As a result of this work, a channel 5 feet in depth and approximately 150 feet in width was obtained at Hilliers.

The old channel in the vicinity of Lock No. 29 was 80 by 5 feet and followed the chute north of the island. The channel through the chute was narrow and crooked and ill-suited for navigation. The project as originally submitted contemplated a channel 200 by 5 feet, which should follow the main branch of the river south of Andersons Island, and do away with the use of the chute north of that island. Four dams were embraced in the project, namely: a trailing dam extending out from one side of the approach to Lock No. 29, a wing dam on each side of the river at the head of Andersons Island, and a closing dam for the chute north of that island. Even then there was some idea of finally securing a 7-foot channel, as is shown by the fact that it was proposed to drill and blast to a depth of 7 feet all rock found above a 5-foot depth. After some discussion, it was determined to work to a 7-foot grade in the 120 feet of new construction, leaving at 5 feet the old 80-foot channel, which, from Lock No. 29 to Andersons Island, formed the northern part of the new channel. Work was started with this idea in view, but after the 120 feet had been worked to a 7-foot grade it was decided to go on and reduce the 80-foot strip to a 7-foot depth as well. It was also determined to make the channel at Hilliers 200 feet wide and 7 feet deep, and estimates are now in preparation which will show the cost of a channel 200 feet wide and 7 feet deep throughout the length of the pool.

Drillboat No. 6, which has been employed in Rock River Pool since April, 1909, is 80 feet long and 20 feet wide. She is provided with three steam drill machines, mounted on carriages, each of which is supported on a small four-wheeled truck. The carriages roll along a track laid about 6 inches from the side of the boat. They are of heavy timber and are about 7 or 8 feet in height. A davit with block and tackle is attached to each carriage and is used for lowering the drill machine to the deck in case repairs are required and for hoisting isolated pieces of rock, which are gripped by tongs attached to the tackle. The carriage serves as a support for the drill machine.

The machine proper is a steam cylinder, which is mounted on a metal cradle. This cradle slides vertically on guides, which are bolted to the main timbers of the carriage, and is moved by an ele-

vating screw with its handle at the top of the carriage. The cylinder itself slides on the cradle, being operated by a second elevating screw. The drill is attached to the piston of the cylinder.

The machine used on this boat is the Ingersoll drill. Steam power is used both for raising the drill after the stroke and for giving power to the blow. The cylinder is 4.25 inches in diameter, with an 8-inch stroke. An important feature of this machine is the valve arrangement, which adds considerably to the force of the blow struck. These valves are so constructed as not to admit steam underneath the piston for the purpose of raising the drill until the full length of the stroke has been reached. This permits the piston to strike a solid blow and apply all of its energy to the material to be drilled. Many drill machines are so built as to admit steam beneath the piston before the latter has fallen the full distance. This steam acts as a cushion and deadens the blow, much of the power of the drill being used against it. The machine is controlled by the two elevating screws above mentioned and by a throttle regulating the admission of the steam, which is carried to the machine by means of a flexible pipe.

The drills used are bars of tool steel from 12 to 14 feet in length and 1.5 inches in diameter. The head is slightly enlarged, being about 3.5 inches across, and has the shape of a cross with equal arms. Each arm of the cross is five-eighths inch in breadth. In case the drilling is in soft material, such as clay, this head is flat; but for use in drilling rock each arm of the cross is sharpened. The flat bits are superior for use in clay and mud, because by mingling the mud and water more thoroughly they leave a comparatively thin mixture behind them. The sharp bits penetrate the material much faster, but leave thicker mud behind. The consequence is that after making a hole perhaps 3 feet in depth they become stuck and can be moved neither up nor down. The drill machine has a rifle bar and collar so arranged as to cause the drill to revolve slightly at each downward stroke. This causes the cutting to proceed evenly as all parts of the hole are reached.

A guide for the drill is attached to the carriage just above the water level. In case the drilling is directly into rock without any intervening layer of sand or gravel, an additional guide is needed to prevent movement in a lateral direction, which would enlarge the diameter of the hole then in progress. This additional guide is attached to a railroad rail, which is put down into the water at the side of the carriage. The guide is so adjusted as to come about halfway between the surface of the water and that of the material to be

drilled. If there is sand or gravel on top of the rock, it will act as a guide for the drill and no second guide is necessary.

A pipe is provided at each carriage for use as a water jet. When drilling in sand, this jet becomes necessary in order to keep the hole clear. The pipe is put down alongside of the drill and washes out the material as it is loosened. In case pure gravel or a mixture of sand and gravel is encountered, it is better to put off the use of the jet as long as possible, since it causes the sides of the hole to cave in behind the drill. This is especially the case in pure gravel, which is about the most troublesome material that a drillboat has to deal with. It is frequently necessary to drill the holes to an extra depth in order to insure getting the charge at the proper spot.

The boat carries an 8-horsepower steam engine, which operates two capstan spools, one at each end of the boat. The transmission of the power is effected by means of gears and a longitudinal shaft running the length of the boat. There is also an 8-horsepower vertical engine which operates a dynamo furnishing current for one arc light and eight or ten incandescent lights. In addition, there is a pump to feed the water jets mentioned above. A central boiler, carrying steam at 100 pounds pressure, supplies all the engines on board. There is a blacksmith shop, which does work for the entire fleet, and whose chief use with respect to the drillboat is to repair and sharpen drills. The drillboat has four spuds, set two at each end, and operated by hand. A single crew for the boat consists of 1 foreman, 1 dynamite man, 3 drilltenders, 3 deck hands, 1 fireman, 1 blacksmith, 1 helper for the blacksmith, and 1 watchman.

Wages vary from \$110 to \$40 per month, subsistence being furnished by the Government.

There are two improvements which seem desirable on the drillboat and which would certainly save time and insure better work. The first of these is the use of steel carriages for the drill machines instead of the wooden ones now on the boat. The wooden carriages lack rigidity and permit the drill and the guides to get out of alignment, so that it is necessary to true them up two or three times during a season. If steel carriages are obtained, an improvement should be made at the same time in the elevating gear for the drill machines. That at present in use is too slow, requiring from 10 to 15 minutes to withdraw the drill from a deep hole. The best way to overcome this difficulty would be to elevate the machine by steam power, a small engine, being attached to each carriage for the purpose. It must be noted, however, that the increased weight of these

carriages and engines might be so great as to make the boats top-heavy. A complaint is also made that the present 4.25 by 8 inch drill machines, while excellent of their kind, lack power and are not large enough for deep drilling. A machine with a 5-inch cylinder and an 8-inch stroke would give better results and carry on the work with greater speed.

In drilling, the boat is held in place both by her spuds and by five mooring lines, one called the head line being carried directly upstream and the other four being attached to the corners of the boat. These lines are all made fast to anchors, and the boat is moved by taking up on the corner lines by means of the steam capstan.

When commencing operations, the boat is placed at one of the downstream corners of the area to be drilled with her head upstream. Since the distance between the extreme positions of the end drill machines is 68 feet, the cut must be of this width. Two poles are set up 68 feet apart in the direction of the flow of the stream to mark the commencement of the cut, and drilling is begun. Holes are drilled 4 feet apart, opposite white streaks painted on the side of the boat to mark the positions in which the machines are to be placed. After one line of holes is drilled, they are loaded and fired, the boat being hauled off about 50 feet before the explosion. She is then brought back, and another line of holes is begun parallel to the first line at a distance which varies from 5 to 10 feet, and depends upon the character of the material and the depth to which the previous line of holes was carried. Proceeding in this manner the boat is pulled across the width of the patch, leaving a 68-foot strip of drilled and blasted material behind her. She then sets two poles to mark the end of the cut, goes back to the side where the work was commenced, is pulled upstream 72 feet and proceeds in the same way, repeating the process until the patch has been entirely broken up.

I remarked above that the distances moved depended upon the kind of material and the depth to which the holes were carried. In this particular work the material was soft, being sand rock and blue clay, and the distance between lines of holes was as great as 10 feet. In hard limestone rock this would have to be reduced to 5 feet. As regards the depth of the holes, it may be said that the deeper the holes the larger the charge of explosive and the farther the boat can move. A general rule often followed is to move back a distance equal to the depth of the holes. It should be remembered that the rock is always to be driven out horizontally and never vertically.

The first idea of the foreman of the work is to open one side of the cut, so as to form a ledge of rock, the face of which he continually blasts off. If he moves back too far from the face the result of the explosion will be a line of craters, leaving a solid edge untouched which he must work over.

Having thus given the theory of drillboat work, it will be well to speak of the method, sometimes employed, of drilling two lines of holes before firing any of them. This method could not, in any event, have been used in Rock River, since the firing batteries did not generate sufficient current to fire so many holes at one time. But, leaving this out of consideration, there are serious objections to the practice.

As long as all the holes explode the difficulties are not so great, although even then there is much to be said against the two-line system. It is plain that unless the line of holes nearer the face of the ledge is the first to explode, the second line will have to work against a very considerable thickness of rock, which it will probably be unable to push out laterally. It will, very likely, expend itself in an upward direction. The evils of this have already been described. The practice in some places is to put no exploders in the first line of holes, relying on the shock of explosion of the second line to set off the first. In this case it is apparent that bad results will be obtained, the causes for which I have stated.

Let us next suppose that some of the holes fail to explode. This contingency is very likely to occur, since, besides the chance of a weak firing current which will not affect all the holes, there are, unless the concussion system is used, double the number of electrical connections to be made and, consequently, double the number of chances for mistakes. If some of the holes do fail, the boat is in a dilemma. A new line of holes must be drilled, of course, but where? If between the old lines, there is a very great chance of striking some of the loaded holes and blowing up the boat. If back of the second line, the ledge is too thick to be blown down, and the explosion will be wasted in driving out a comparatively small amount of rock in a vertical direction. It seems difficult to say what would be the best thing to do under such circumstances.

This seems to be the proper place to explain shallow digging, and its effect on the apparent work done by the drillboat. The boat is only given credit for the rock which it blasts above grade. For example, let us suppose that a channel is to be deepened to 7 feet, and that its present depth is 6 feet. Now, in order to get any effect from

the explosive, it is necessary to have the holes not less than from 3.5 to 4 feet deep. The bottom of the holes in our example would be from 9.5 to 10 feet below the water surface, and the resulting explosion would loosen the rock to a depth of, let us say, 9 feet. Now, the boat has actually blasted 3 feet of rock from 6 to 9 feet below the water surface, but is only credited with the 1 foot necessary to bring about the 7-foot channel required. If the rock level had been but 4 feet below the surface, and holes of similar depth had been dug, the boat would have done no more actual work, but would receive credit for the 3 feet between the 4 and 7 foot levels. Thus, in the case of slight lowering of grade, the boat gets credit for only a small percentage of the work actually done. If it is not desired to do so much useless work below grade, the only recourse is to dig shallower holes. This requires the use of a smaller charge, and, as a consequence, the boat can not move so far before digging another line of holes. Hence, more digging must be done to get over the same area, and the boat loses time by frequent moving. No matter which plan is followed, the work of the boat as measured will inevitably suffer. The measurements for the calculation for work done are taken before drilling is commenced, the material being in place.

In loading a hole, the first operation is to insert in it a three-fourths inch iron rod. This serves as a guide for the introduction of a brass tube 3 inches in diameter, which has a 1-inch slot extending its whole length for the firing wires to lead through. The tube having been inserted in the hole, a 1-inch water jet at from 40 to 60 pounds pressure is used to thoroughly wash out the hole. This process being completed, the rod and jet are withdrawn, and the explosive is dropped into the tube, the firing wires passing through the slot spoken of above. The charge is shoved into place with a wooden loading stick and the tube is withdrawn, thus completing the operation. Ordinarily, about 4 pounds of 50 per cent dynamite is used in each hole.

The operation known as sweeping is conducted for the purpose of making sure that the work has been thoroughly done, and that no lumps have been left untouched above the proposed grade. The method employed is determined by the speed of the current.

In a slow current, the boat is taken to the upstream side of the patch and set across the stream. Two railroad rails are then lowered on the upstream side so that they shall be exactly at the proposed grade. These rails, together, are 60 feet in length. The boat

then proceeds downstream by swinging on her spuds. If she passes over anything above grade, it will hit the rail and carry it out from the side of the boat. This will be shown by the movement of the line supporting the rail. When any such obstructions are found, the boat is stopped and proceeds to remove them. If only a small rock above grade is found, it is taken out by means of tongs, which are fastened either to the davit placed by the side of each drill carriage, or to a cross pole which is laid on the roof of the boat. If the rock is too large to remove with the tongs, or if an extensive patch of rock is met with, blasting operations and the use of the dipper dredge must be resorted to. At times, rocks can be broken into pieces small enough for the tongs to handle by exploding cartridges either on top of them or in very shallow holes.

This process is repeated until the whole width of the patch has been swept. Each sweep is made to overlap its predecessor by about 10 feet in order to insure a clean piece of work, a line of buoys having been previously dropped to mark the edge of the preceding sweep.

In a swift current this process must be somewhat modified. The rail is used, but is suspended from outriggers so as to hang about 4 feet from the side of the boat. An anchor is put down in the river about 200 feet above the beginning of the patch to be swept. The head line of the boat is attached to this anchor, and the boat is swung from side to side on the head line, movement being given by the corner lines. At the end of each swing 50 feet of head line is let out before the next is commenced. The rail is, of course, liable to be carried in either direction, since the sweeping is over a fresh area at each swing, and the outriggers are necessary in order that a movement of the supporting lines in either direction may be readily seen. Sweeping should always be the last operation performed, in order to insure a clean piece of work.

DISCUSSION

R. MONROE

Assistant Engineer

Relative to the latest method of rock excavation used in this district, the report by Lieut. J. M. Wright, on Rock Excavation in Rock River Pool, gives an excellent description of the subject.

The conditions in Rock River Pool do not differ materially from those in the Mississippi River, and the methods used are those adopted after many years of experience on the Rock Island Rapids work on the Mississippi River.

The equipment, as stated by Lieutenant Wright, is not as efficient as might be desired in some respects; in particular, an appliance of some sort to replace the slow motion screw for removing the drill, after the required depth of drilling has been reached, would, perhaps, be a time-saving improvement. In a general way, the successful results obtained are due, probably, to the methods, rather than to the excellence of the equipment in use.

In Rock River Pool, a wide variation is found in the character of material requiring drilling and blasting, ranging from hard clay and soft sand rock to a very hard lime rock, and is what would be termed shallow drilling, ranging from $3\frac{1}{2}$ to 7 feet. The material, after being drilled and blasted, is removed by dipper dredges and loaded on to dumpboats or barges and usually towed to some construction work, where the broken rock can be used for riprap, etc.

The usual method of excavating rock is as follows: The patch of rock is outlined, or the proposed channel is marked through the rock patch. This is done, usually, by setting hardwood poles, 3 inches in diameter and from 15 to 20 feet in length, into drilled holes from 3 to 4 feet deep around the area to be drilled and blasted. After the drillboat is put in position, as described by Lieutenant Wright, and the first line of holes blasted, a careful examination is made to see whether or not the dynamite has had the desired effect. The first line of holes is, necessarily, a sort of test to determine the amount and strength of dynamite required. It is customary to try the first line of holes with about 1 pound of dynamite per foot of depth of hole. In very hard lime rock, free from seams, the amount of dynamite may have to be increased to perhaps $1\frac{1}{2}$ pounds of dynamite per foot of hole. A general rule is to use enough dynamite to insure getting well broken rock. Many attempts have been made to determine the strength of dynamite best adapted to this work; combinations of slow and quick-acting and dynamites ranging from 40 to 100 per cent have been used at different times. At the present time a 60 per cent dynamite, manufactured by the Aetna Powder Company, is being used. After blasting the first line of holes a special effort is made in each successive line to keep a good face to the ledge, *i. e.*, to keep the rock blown out to about the full depth of drilling. If the lines are placed too far apart in shallow drilling, *i. e.*, from 3 to $4\frac{1}{2}$ feet, there is a tendency to blow off the top, leaving the bottom toward the face of the ledge undisturbed, and in deep drilling, *i. e.*, over 5 feet, there is a tendency to blow back underneath the ledge as well as to blow out the top. To obtain the required depth after dredging, it has been found necessary to drill and blast to 3 feet below the required grade in lime rock and about 2 feet in hard clay.

After drilling and blasting has been completed, or a sufficient area has been covered, dredging operations are begun. The keynote to successful rock dredging is to be found in the skill and care of dredge operators. In river improvement our prime object is to reduce the excavation to grade, or slightly below. It is necessary to work to a little below grade to insure leaving no projecting points. In dredging with the ordinary dipper dredge, there is a tendency to push the material forward, in line with the direction of action of the dipper. In other words, at each position of the dredge a comb of material is pushed forward just out of reach of the dipper to be gathered and followed up from the next position of the dredge. To avoid leaving these combs or ridges, it is evident that they must be followed by the dredge to the outer edges of the

channel. Our practice is, where possible, to start in on one side of an area to be dredged and by taking narrow cuts, *i. e.*, about one-half the possible width of cut, keep the comb of material always on the side of the area to be dredged, and to keep working the dipper of the dredge continually in that direction. Thus any material pushed forward and not caught in the dipper may be picked up from the next position of the dredge. All material is loaded into dump-boats or barges and towed by steamboat to destination.

While extreme care has been taken to dredge the area to grade, and close examination with the sounding pole may show the desired results, yet it is quite necessary to make a further test to make sure that grade has been obtained throughout. This final operation is called sweeping and, as described by Lieutenant Wright, any and all projections above grade are located by the suspended railroad rail and removed.

J. C. QUINTUS

Principal Assistant Engineer

Rock excavation has been carried on by the United States on the improvement of "Lake Erie Entrance to Black Rock Harbor and Erie Basin" and "Black Rock Harbor and Channel" at Buffalo, N. Y., requiring the removal of from 2 to 17 feet of the hard limestone rock of the locality to the depth of 23 feet below the water level of Lake Erie.

On the "Lake Erie Entrance" improvement, under contract 1903-1908, the amount of rock removed was 346,000 cubic yards, place measure, and all was first drilled and blasted and then excavated by dipper dredges. The plant employed, drillboats and dredges, was of the best type in use on the Great Lakes. Five drillboats were operated on this work, each equipped with from two to four drills. The 4-drill boat, *B. D. Co., No. 1*, is an improved machine, but not the latest. The hull is of steel, 106 feet long, 30 feet wide, and 6 feet deep. The house is of wood, 86 feet long, 18 feet wide, with a sloping roof 12 feet high on the drill side and 11 feet on the opposite side. There are four drill frames, each equipped with a Rand No. 5 drill attached to a hydraulic piston hoist for raising and lowering the drill. Hydraulic pressure is furnished by a large pressure pump.

The drills are operated by steam supplied by a boiler 12 feet long, 7 feet diameter.

The drill frames rest on rails laid on the boat's deck, and are moved by rack-and-pinion by hand power.

The water and steam pipes supplying water and steam to the hydraulic hoists and drills, respectively, are arranged and furnished with flexible joints so as to adjust themselves readily to every change of vertical or horizontal movement of drill frames and drills.

A supply of from 2 to 2½ inch drill rods is kept on hand, the X-bits being kept in order by a blacksmith and two helpers, supplied with a large forge and hydraulic hammer.

In operation, drillboats are held in position by anchor spuds, one on each corner of the hull, which are raised and lowered by hydraulic pistons.

In drilling, holes are spaced generally 4 feet apart and carried to a depth of from 1 to 2 feet below grade. Each hole is charged when completed and before the drill is moved; and holes are fired separately or all in the line drilled for one position of the boat fired together, as conditions may determine. In deep water a line of from ten to twenty holes, each charged with from 2 to 5 pounds of 60 per cent dynamite, may be fired together without moving the drillboat away farther than the 4 to 5 feet required to set on the next line; but in shoal water and where holes are charged with from 10 to 20 pounds of dynamite each, the drillboats should move back 50 feet or more.

For outline drawings of *Drillboat No. 1* and photo prints, see Engineering News, Vol. LIV, No. 1, July 6, 1905.

For table showing work done by drillboats, holes from 4 to 5 feet depth, see Report of Chief of Engineers, U. S. A., 1904, page 3265.

On the Black Rock Harbor and Channel improvement, begun under contracts in 1907, in progress in 1910, the plant and methods employed are generally the same as were those on the Lake Erie entrance work.

Two new 5-drill drillboats, *B. D. Co., No. 5* and *Empire Engineering Corporation No. 1*, constructed entirely of steel and embodying the latest improvements, are, however, in operation on the Black Rock work.

These boats are 137½ feet long, 32 feet wide, and 6½ feet deep. House, 112 by 20 feet, 13 to 11 feet high. They are fitted out in general similar to *B. D. Co., No. 4*, previously described, but on account of troubles in freezing weather steam power is used, instead of hydraulic, for hoisting drills and moving drill frames; also for hoisting spuds. Steam for all purposes is supplied by a 125-horsepower Scotch boiler. A Dake engine is attached to each drill frame, which drives a drum 15 inches long, 12 inches in diameter, with ½-inch cable attached to the drill for raising and lowering it. A sprocket wheel on each of the drum shafts also engages a fixed chain running parallel with the drill side of the boat and over each sprocket in succession. A clutch connects the engines to the sprockets, and thus each drill frame is moved along the track as desired. Drill frames are held in position, while drilling, by rail clamps. Anchor or spud hoist consists of a two-cylinder engine at each spud, operating a pinion engaging the rack on the spud.

The drills are Ingersoll-Rand No. 6, cylinders 38 inches long, 7 inches diameter. Drill bars are of steel, 31 feet long with 2¼ to 2½ inch bits. The dynamo current for electric lighting is also used for firing blasts.

Two Lobnitz rock-breaking machines are also in use on the Black Rock Harbor and Channel work, where from 1 to 17 feet of hard limestone rock, in strata from a few inches to 2 feet or more in thickness, is to be excavated.

The table on the following page shows the efficiency of these machines:

Lobnitz Rock Breaker.

	Tonawanda.			Tuscarora.		
	Season of 1907.	April- August 1908.	Total.	Season of 1907.	April- August, 1908.	Total.
Total time in commission, days of twenty-four hours each.	253	110.5	363.5	235	87	322
Days of twenty-four hours each on which some work was actually done.	150.5	110.5	261	155	87	242
Proportion of latter time actually worked, per cent.	32	78	52	43	77	55
Contractor's estimate of rock crushed, cubic yards, place measure.	10,451	16,825	27,276	12,538	12,689	25,227
Average per day of attempted work, cubic yards.	69.4	152	104	80.9	145.8	104
Average depth of holes, feet.	-----	-----	2.12	-----	-----	1.75
Spacing of holes.	4 ft. $\times$ 5 ft. to 5 ft. $\times$ 5 ft.			-----		

The table gives a fair average of what can be done with these machines in hard rock, but the estimated amount of rock broken is probably excessive by from 20 to 25 per cent, being the contractor's estimate.

These machines might operate efficiently in thinly stratified rock of medium hardness, where removal is limited to 3 or 4 feet depth, that can be broken to grade in one operation. Where rock can not be broken to grade, requiring going over the same ground repeatedly with rock breaker and dredge, the progress is slow and the cost consequently increased.

The Lobnitz machines in use were built by the Empire Engineering Corporation.

So far as can be learned from Mr. F. W. Allan, the company's superintendent, the matter of patent control in the United States is not known and is being investigated at Washington by the company.

The Empire Engineering Corporation purchased the hoisting engine only from Lobnitz, Scotland, and erected the machine themselves. The hoisting engine has no special features and is considered inferior to a good American make. Mr. Allan is of the opinion that Lobnitz patents control only special features of the hoisting engine, adapted to quick release and easy run-off of hoisting cable from the drum. The hoisting cable is required to be rigged "single whip" so that the drop may be efficient. This requires a strong engine for hoisting. The rams in the machines here weigh 15 tons and 22 tons, and the length of ram used depends on the height of the rock; a short ram being necessary where rock is high in order to secure enough hoist for an efficient drop. The "drop" ranges from 10 to 20 feet.

The rams are parts that give much trouble in hard rock, such as met with here.

Rams with removable conical steel points of special foreign and domestic make are used. These points wear away rapidly and some have broken off, involving much delay and expense in removing the shaft left in the socket. A Krupp ram of 15 tons with a hard steel blade point welded into the softer steel ram was tried. The ram was operated with fair success for several months, but finally broke in two just above the upper end of the blade, which extended up into the ram about 5 feet.

The rock breakers in use here are held in place by four cables to anchors. This implies slow movement in changing position and the cables obstruct navigation. The use of spuds is not considered feasible.

J. B. BASSETT
Assistant Engineer

The principal changes from the drillboat described by Lieutenant Wright, as seen on the drillboats on the Great Lakes, are those of size and modern equipment for handling the drilling machines for a saving of time.

The size of hull varies, but is usually between 130 and 140 feet in length by 30 to 32 feet wide, and from 6 to 8 feet in depth. Some of the hulls are built of wood and some of steel. One of the owners of a steel-hull boat stated that he believed steel to be the proper material for use, but others have stated that in their opinion its life would be short on account of crystallization from the

constant vibration. It has been said that a considerable quantity of rivet heads could be picked up inside the hulls. Anyone familiar with drillboat work knows of the constant vibration, and it would seem as though the wood construction would be preferable, but the fact remains that most new drillboats have steel hulls.

Spuds are located on the extreme ends of the hull instead of in spud wells and, owing to the much greater depth of the lake work, are much larger, being usually about 20 by 20 inches in section and something over 40 feet in length. They are operated in most cases by a double cylinder reversible engine geared to a rack in the spuds. In some cases, a centrally located engine operates all spuds by means of shaft connections and clutches, actual connection to the spud being made by use of cables, but the former arrangement is more common. It is customary to rack the boat up on the working side so that the deck is somewhat inclined to avoid the possibility of slipping from its position. Ordinary steam capstans are provided on all boats for movement on anchor lines.

The principal difference in the drilling machine itself is in the size. The 5½ by 8 inch cylinder drills have proved most effective. Drills with 6-inch diameter cylinders have been used, but did not prove successful. In the language of the drill operators, "They hammered themselves to pieces." A matter of this kind could probably be remedied by a redesign of the cylinder. The newer drills in use have an arrangement for throwing in an air or steam cushion under the piston to absorb the force of the stroke when a clay seam or soft material is encountered. This allows the drill to continue in action and "mud out" the soft strata. The writer has a drillboat in his charge with a so-called "automatic" valve drill arranged so that the piston stops when soft material is encountered. This saves hammering the head of the drill, but it wastes considerable time in working the drill up and down until a hole is made through the soft material. The bits used are similar to those described by Lieutenant Wright, except that the stock is slightly heavier. The diameter of the cutting point is usually 3½ inches.

The method of moving the drilling machine vertically is entirely different, the use of feed screws being entirely done away with. The drill casting is bolted directly to a steel plate which slides up and down in the leads of the drill carriage, much the same as an ordinary pile driver. The lifting power is applied directly to the steel plate. In most cases hydraulic cylinders are used, but one of the newer boats was fitted out with a steam rotary engine on each drill carriage. With the hydraulic method, a vertical cylinder stands on the carriage directly back of the carrying plate, with its piston rod attached directly to the top of the plate. The length of the hydraulic cylinder is about 14 feet, but this, of course, may vary according to the vertical lift desired. With this system the drill carriage, which is constructed of steel, must have considerable height, as the height of the cylinder itself is added to the lift. The water connection is made at the bottom of the cylinder by a pipe running horizontally across the carriage platform and connecting by a radial pipe with telescopic joints with the main hydraulic feed line at the upper edge of the cabin wall behind. This allows for lateral motion of drill carriages along the line of the barge. The steam connection for the operation of the drill is provided with a similar radial telescopic pipe lying parallel to and about 1 foot from

the water pipe. In the case of the steam line, there is a telescopic joint at the side of the plate to allow vertical motion of the drill. These pipe connections do away entirely with the use of steam hose operation. The control of the vertical motions of the drill is by a pair of valves in the water pipe near the floor of the carriage, both being controlled by one lever. One valve raises the cylinder and the other slacks it down by releasing the water under the piston. Where the rotary engines are used, the power is applied by a cable from the engine drum running over a sheave at the top of the carriage and then down to the drill plate. The engine power is applied for lifting the drill, the weight of the drill controlled by a foot brake on the drum being sufficient for the downward motion.

The lateral motion of the drill carriage on the hydraulically operated boats is by an additional hydraulic cylinder lying on the inside of the boat cabin, but parallel to the line of carriage travel. It is arranged to work in either direction and has a continuous chain connected to ends of both piston rods. The chain leads directly to the ends of the scow, then through direction sheaves and along the edge of the scow directly under the drill carriages. When desired to move a carriage, the chain is caught up by the operator and fastened in a fork attached to the carriage. A signal is then given to an operator at the cylinder and the carriage is moved the desired distance. The travel of this cylinder is not as great as the entire distance covered by each carriage, and in case this distance is to be covered at one time, it is necessary to drop the chain and overhaul the cylinder and begin over again. On the boat equipped with rotary engines, the lateral motion of the carriage is acquired much more easily and quickly. A chain with each end attached to the deck lies under each carriage and is run through a chain sprocket, which is operated by a clutch from the engine. The clutch is reversible and motion in either direction is quickly attained. The writer noticed an operator move from one hole to another in a few seconds. The action was not anticipated and so was not timed, but the move was made with such rapidity as to attract his attention.

The use of a wash pipe is noted by Lieutenant Wright. The same method of cleaning holes is used on the Lakes by some of the boats, but is usually kept in operation simultaneously with the drilling. One boat foreman boasted that it was not necessary and showed where arrangements were made for only temporary connections for a water line, but at the time of the conversation the writer noted that all of the drill operators, except one, had finished their allotment of holes and their machines were idle waiting for the slow operator, who was having trouble with gravel. That seemed to show that a wash-out pipe was needed, and it is thought that it is an advantage on most any kind of drilling.

Another attachment which is used on the Lakes and on the drillboat of which the writer has charge, but not mentioned by Lieutenant Wright, is the so-called "sand pipe." It consists of a pipe of 6 or 8 inches diameter held loosely in a collar suspended by a guide rail from the drill carriage, through which the drill works. It is let down to the bottom where the rock is not absolutely clean. It is held so that as the drill-bit strikes the loose gravel or sand overlying the rock it throws it aside and allows the sand pipe to settle. As this process continues the pipe eventually reaches the solid rock and forms a well in the loose material. The pipe is left in place until the blasting charge has been placed.

The pipe is varied in length according to the amount of loose material liable to be encountered. It has been used on the work in charge of the writer with considerable success.

The question of the number of drills to be used on one boat seems to be a matter of much discussion. Some of the older boats have only three, but all of the newer ones have four or five. One of the owners of a 5-drill boat stated that a boat with four or possibly three drills is more economical on account of lost time in case one drill is working in poor rock and delays the progress of the boat as a whole. If this argument is continued, it would seem as though the 1-drill boat is the best, but here the question of general progress on the work should be considered.

The contractors on the Lakes seem to differ greatly on the question of the number of holes to fire at one blast. Some of them fire a hole at a time as fast as it is drilled; others fire one row the length of the boat at a time, and others fire large fields. In the case of the latter, only a few primers are placed in the last row, the balance of the holes exploding by concussion. The writer holds the opinion that a better effect is produced on the rock if more than one row is discharged at a time, and is conducting his work on the two-row system. The trouble in getting satisfactory results from the firing batteries, mentioned by Lieutenant Wright, was encountered, but the idea of using the electric current from the lighting dynamo was thought of. The dynamo on the boat is of an antiquated type, and the question of the feasibility of the idea was put up to a prominent powder company. Their scientific department finally rendered an opinion that the dynamo could not be used, but our ingenious drillboat foreman tried it out by the use of a short-circuit and has been firing two rows at a time in this manner with success during the present season.

The practice on the Lakes as to depth of holes below grade and distance apart of rows is uniform, being 5 feet in each case.

All of the boats have well-equipped blacksmith shops in addition to the usual boiler plant, pumps, etc. A coal bunker with capacity of from 30 to 40 tons is also provided. Illumination for night work is provided by either an electric or a gas plant.

DISCUSSION: REDOUBTS AND FIELD FORTIFICATIONS.

(Continued from page 456)

mish lines, together with the unoccupied spaces between those individuals. Considering the target as a whole, it has great width and considerable depth, but a great number of bullets must hit the target before any damage is done to one of the individuals. Now precisely the same tactical considerations indicate that defensive works should be so dispersed in lines both parallel and perpendicular to the plane of fire that of thousands of artillery projectiles striking the target (*i. e.*, the "belt" or strip of terrain occupied by the scattered works) but one may strike anything vulnerable, and so that even the effect of the striking projectile may be extremely local.

To secure the greatest possible invulnerability to artillery fire the individual works should be simple trenches plentifully supplied with shrapnel proofs and bombproofs, and never one behind the other, unless at a considerable distance from it. Did the terrain permit and were no other considerations than artillery fire involved, the trenches might be so short as to constitute each a pit or shelter for one man; or even without much sacrifice on the score of invulnerability to artillery fire, a single continuous trench, traversed occasionally, might be employed; the dispersal in this case being lateral only. Other considerations, however, in the general case would prohibit the use of the continuous trench or the isolated pits.

To meet the conditions of invulnerability to night attack (1) there must be no weak intervals in the line, (2) the parts of the line must be in defensive relations one to another.

A continuous trench would meet the first condition but not the second, for if by night attack an enemy were to make a lodgment in a continuous trench it would be very difficult to prevent him from pursuing his success and the whole line would be threatened. On the other hand, it would appear to be dangerous too greatly to strengthen some parts of a line with a view to the formation of what have been called "tactical pivots," for such strengthening would necessarily be at the expense of other portions of the line, which would therefore offer greater opportunities for night attack.

To sum it all up, it is necessary to remember that the defensive works should be of such character and distribution as (a) to insure for the defending personnel the greatest practicable immunity from losses due to artillery fire, (b) to bring against infantry attacking in daylight the maximum of fire from trenches so disposed that the fire from those in rear will sweep the flanks of those in front and generally command them, and so that an enveloping fire may be brought to bear against any portion of the line (belt) which may be penetrated by the enemy, and (c) to leave no important intervals for night attack.

I would not be understood as deprecating entirely the use of simple redoubts such as that under consideration; but I do think that if we were to go to war

to-day there would be a tendency to use too many of them, to the neglect of simpler works perfectly disposed.

In order to make myself more thoroughly understood, I have endeavored to illustrate in the accompanying rough sketch what seems to me the proper distribution of works.

Ordinarily, a "position" is a ridge and the slopes of a ridge are, ordinarily, combinations of spurs and ravines. Therefore the terrain I have shown by contours on the sketch is more or less typical of nearly all positions, as a little thought will readily show. No attempt has been made to show the communications nor the obstructions, and, to simplify matters, no discussion of them has been attempted above.

Some of the trenches shown might be transformed into redoubts, if time permitted, but in the first instance I think the defensive belt should be somewhat as shown. Those developed into redoubts would probably be those furthest to the front and those furthest to the rear in the re-entrants.

MAJ. WM. D. CONNOR

Corps of Engineers

While it is almost certain that both the front and rear trenches of a supporting point will not be occupied during the early stages of the attack, it is probable that the bombproof and the forward line of trenches will be occupied during that time, and that is the reason why the 50 yards between the two is important. An additional reason is the damage that can be done to the actual works themselves by the enemy's fire.

The bombproof shown in Fig. 11 was designed as a protection against field artillery only, and, in case the attack became serious enough, the cover would have to be increased to get satisfactory protection against siege artillery.

Of all the kinds of head cover that have come to the writer's attention, the sand bag appears to be the best. These bags are filled and kept in the bottom of the trench until the moment for opening fire on the advancing troops, when they are placed upon the crest. Such a head cover offers no conspicuous target to the enemy's artillery in the early stages of the attack and is admitted to be very effective.

The slight disadvantage of the diverging fire from the curvilinear front must be weighed against the advantage that is obtained from the lack of visibility existing in a trench that follows the contour as against one with a straight front which necessarily would not follow the contour. It is believed that the concealment afforded would more than offset the disadvantage of a slight divergence of fire. In the same way, we must measure the value of the ease of control in a continuous trench against the lack of control which exists in a non-continuous trench.

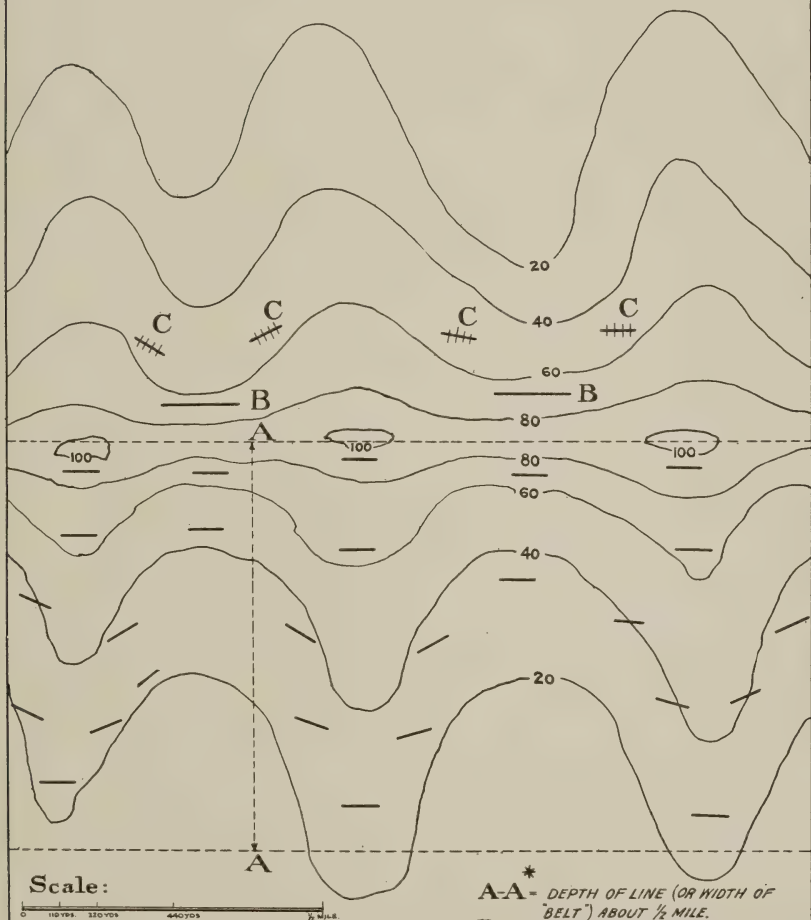
A fixed type of trench is indefensible; a general type, however, is indispensable. The difference between the two is very great; a *fixed* type hampers the engineer, but a *general* type gives him a concrete idea which he knows must be varied to suit the local conditions. Without a general type there can be no concrete idea.

Small offsets in communicating trenches are of little or no advantage, owing to the width of the cone of dispersion; and very little cover will be afforded

D



ROUGH SKETCH ILLUSTRATING DISPOSITION
OF WORKS IN A TYPICAL POSITION.
THE COMMUNICATIONS AND OBSTRUCTIONS
ARE NOT SHOWN.



Scale:

*
A-A = DEPTH OF LINE (OR WIDTH OF
"BELT") ABOUT 1/4 MILE.
B = BOMB PROOFS FOR SUPPORTS.
C = TYPICAL ARTILLERY POSITIONS
D = RESERVES FOR THIS PORTION OF LINE.

*
= INFANTRY TRENCH
*A-A MIGHT WELL BE EXTENDED TO REAR
TO INCLUDE ARTILLERY POSITIONS.

by these offsets as traverses, on account of the sharp angle of fall of the projectiles. It is believed that the curvilinear type gives equal protection, although it is admitted to be slight; passage through these trenches must be hurried, and they are not built for permanent occupation.

The suggestion of a double row of wire entanglement seems to be very good and to give more protection with little or no increase in the amount of labor.

The whole idea of the supporting point described in the original article was that of giving the least possible depth to any part of the work, and this was accomplished by use of narrow trenches. The minimum interval of 50 yards adds to the security by making two narrow lines, each of which is outside of the bracket that must be used in firing upon the other. If the quality of the fuses or the difficulty of observation widens this beaten zone to 150 yards, the deadly effect of accurate artillery fire will be entirely lost.

It is assumed in one of the discussions that all the troops will be in the bombproof during the early stages of the attack. This would not be the case. The forward line of trenches would certainly be manned and only a portion of the troops would be in the bombproof. For safety, the trenches are equal to the bombproof, but for comfort to the men the bombproof has a very considerable advantage over the trenches. The trench shown in Fig. 1 gives complete protection for a man crouching and can, of course, be deepened and widened to give complete protection to a man standing, if time and workmen are available.

The elevation of the firing crest is greater than that given by the engineer manuals of most armies, and is the general type for an open pasture. The crest can be raised in a field, of corn or in a woods, as shown in Fig. 10. Owing to slight irregularities in the terrain, it is seldom that the entanglements can not be placed so as to interfere but little with the field of fire.

The objection to placing the bombproof under the forward trench is that in every case the field of fire must be cleared, and this means that all the work of building such a bombproof must be in excavation. When the bombproof is in the rear, advantage can be taken of a hollow or of the concealment afforded by woods, and the bombproof can be constructed partly or entirely above the ground. The better sanitation of the latter location is believed to be considerable, and the greater ease of construction and drainage is unquestioned.

The reasoning in the original article leads to the conclusion that there is no intermediate class for a supporting point between an open trench and the closed work. By closed work is not necessarily meant one with a continuous trench, but it does mean a continuous obstacle and fire in all directions. There seems to be no difference between Captain Sherrill's open lunettes and the open trench suggested in front of the redoubt when the slope in front of the same is steep enough to allow the troops in the trench and redoubt to fire at the same time. In the great majority of cases this can not be done advantageously, for only one line can fire at a time. To place part of the troops in the back line where they can not fire during the critical period is simply dividing your forces in the face of the enemy. It seems very wasteful of men to place the main body in such positions that only about one-half or two-thirds can fire during the close and critical period of the attack. If they are to hold more than one line, they must occupy these lines from the start, for it is practically admitted that there is no stopping a routed line of troops at a second line of trenches a few hundred yards in the rear of the first line.

If there are more troops than can be readily put on the front line or if the rear ones are to be held by reserves to be brought up at the last moment, the second (rear) line of trenches will be very effective, but it seems unwise to put a large part of the original defenders into trenches where they can not take part in the stage of the attack which should turn the current of affairs in their favor, that is, while the attack is passing over the space from 800 yards to 100 yards in front of the trench line. This is the reason that leads me to differ from the arrangement shown in Major Judson's sketch. If the original defenders are to occupy permanently all the different positions shown, we have but a small proportion of them available at one time. If the forward trenches are only to be held temporarily, as advanced positions, and the forward troops are to fall back to some main line, ordinary troops will reach the main line already half defeated and may not stop where wanted. In ordinary country it is found difficult enough to obtain a fair field of fire half a mile wide for a single line of trench, and to find a position where all trenches in a belt half a mile wide cover practically the same field of fire is to presuppose a flat field for at least half a mile in front of the forward trenches of Major Judson's sketch. If such a field of fire is available, there is no necessity for several lines of trenches or for many redoubts. An open field a mile wide could not possibly be crossed in daytime against the fire from a single line of trenches held by one man to the yard.

The darkness of night cuts down any field of fire to a few hundred yards at most, and to meet a night attack it appears as though to get the best results all available troops should be formed on a fairly uniform front.

The type of supporting point described in the article is practically the same as that of the Germans, although it was designed as described, after having discarded the German type as too extreme. A thorough study was made of the desirable and undesirable characteristics of a supporting point. The foregoing type was thus built up, and the writer was very much astonished when, at the end, a type almost identical with the previously rejected German type was found to be the result.

THE FINAL STRUGGLE FOR 203-METER HILL AT PORT ARTHUR*

(Reprinted by permission of the Royal Engineers Journal)

One of the most brilliant episodes in the defense of Port Arthur, and incidentally in the military history of the Fifth East Siberian Rifle Regiment, was the ten days' fighting in November and December, 1904, on the position called by the Russians Visokaya Hill. This position received two separate attacks from the Japanese in September, from the 19th to the 22d, inclusive, and again from the 26th of November to the 4th of December. In September the Japanese were repulsed by the heroic action of certain distinguished individuals; in November and December countless brilliant actions were performed, but the Russians did not succeed in holding the hill.

The September fighting has been described often, and its details are fairly well known; all that is known about the second attack is that the Japanese pulverized the hill with 11-inch shell, and after a desperate resistance took it; but of the details of the defense, how it was carried out, to whom the credit for such obstinacy is due, what heroic deeds were performed in the course of the ten days' struggle, and by whom, little is known. Even in the Court of Enquiry on the Defense of Port Arthur, when less important events which occurred on the right flank were described in great detail, scarcely a word was said about the final struggle for Visokaya Hill, although it was this fighting particularly which brought about the fall of the fortress.

With the desire, therefore, of doing justice to the gallant, but hitherto forgotten, defenders of Visokaya Hill, it is proposed to describe in comparatively few lines the events which occurred on each day of this historic struggle, and to dwell at greater length on the noteworthy incidents and heroic deeds of individuals which occurred during the fighting.

It may be allowed with justice that each of the general officers concerned in the defense sought out every device and used every endeavor to keep the hill; General Kondratenko always watching the fight personally, and so attentively that nothing escaped him, sending up in good time reinforcements, food, grenades, cartridges—in fact, everything that was necessary; General Irman almost daily visiting the hill, and by his reckless bravery, better suited to the ardor of youth, encouraging and charming all; and General Stessel carefully following the fighting, at the critical moment placing General Tretyakov in immediate charge of the defense, cheering the troops with kind messages and rewarding on the spot those who distinguished themselves. In a word, each did

*Translation of an article by Staff-Captain Kostiushko in the March, April, and May numbers of the Eenzhenernee Zhoornal.

what he could, but the heaviest and most difficult part, and at the same time the most important, the immediate responsibility for the defense, fell to General Tretyakov, the commandant of the Fifth East Siberian Rifle Regiment, who remained on the hill for six days continuously, again and again leading the troops to the attack, by his personal skill doing great deeds with small numbers, and repeatedly repulsing an enemy who outnumbered his men fully ten times over.

But in publishing the present account one reservation is necessary. The reader must not imagine that it is either perfect or complete; he must understand that, in addition to the whole of the Fifth Regiment, many other troops took part in the defense, combatant, non-combatant, and composite companies of other regiments, sailors, town guards, and hospital detachments. In a word, all who were found alive in Port Arthur, and could handle a gun, were collected by Stessel and Kondratenko and despatched to Visokaya Hill. Consequently, from first to last, there were on this ill-fated hill representatives of not less than eighty different companies and detachments. In some cases even parties of a few men each were joined together in twos and threes, and were sent off to the hill, where they melted away with appalling rapidity and were seldom heard of again. It is, consequently, exceedingly difficult to fix exactly when certain companies were on the hill, and how they were disposed, and to obtain all the information necessary for a complete and accurate description of the fighting. In an earnest desire to give full credit to all, the writer has supplemented his personal observations with information obtained from various reports and from the evidence of others who were present, and, consequently, if any errors or omissions are to be found in this account, they were certainly not premeditated.

Furthermore, he feels sure that it would be difficult to find a more accurate account of this historic fighting, or anyone better qualified than himself to make it out, for the following reasons:

- (i.) That through him as adjutant, Fifth East Siberian Rifle Regiment, almost all the reports and orders affecting the section attacked passed.
- (ii.) That the descriptions of the fighting sent in subsequently by the companies of the Fifth Regiment also passed through his hands.
- (iii.) That, not satisfied with these official details, he also collected many statements from men who took part in the fighting, and
- (iv.) That he himself also took part in it.

DESCRIPTION OF VISOKAYA HILL AND ITS DEFENSES

The town of Port Arthur consisted of two parts—the western, called the New Town, and the eastern, called the Old Town.

On the northwest of the New Town there lay a low ridge of hills, called the Jagged Hills.

The highest point of this ridge attained an elevation of 700 feet (203 meters) and lay about 2 miles from the New Town in the direction of Louisa Bay, *i. e.*, west-northwest.

Its two-pointed summit and very steep sides gave it the appearance from a distance of a two-humped camel. The Russians called it “Visokaya” (great), and the Japanese “203-Meter Hill.”

The approach to Visokaya, and also to Flat and False hills, lay along a ravine named after the tea house of the Eleventh Regiment, which was built before the war, at the northwest extremity of the New Town, in the mouth of

the ravine. Being well covered along its whole extent by low but generally steep hills, and therefore well suited for the concealed movement of troops, the Tea Ravine formed a safe approach to the very foot of Visokaya Hill, which itself protected it on the third or western side. This ravine in places attained a width of 100 paces, but it was generally considerably narrower. A cart road leading to Visokaya Hill ran along it.

Visokaya Hill attracted notice as being a fine and naturally strong position. It was higher than all the neighboring hills except Lyaotesshan, and commanded both the surrounding country and also the forts of the center and eastern fronts of Port Arthur. It was undoubtedly the tactical key of the west front of the land defense, and to a certain extent that of the whole Port Arthur position.

Besides this, a wide view could be obtained from it in all directions; many of the buildings of the Old Town could be seen from it, while the whole extent of the Tea Ravine, the whole of the New Town, and the inner roadstead where the fleet had taken shelter, lay at its feet.

On the 2d of June, 1904, the whole extent of the Jagged Hills, which included Division, Three-Headed, Side, Forward, Angle, Saddle, Deadly, Long, Flat, Visokaya, False, and Intermediate hills, was placed under the command of the commandant of the Fifth Regiment, and not till then was their fortification taken in hand seriously.

Previous to this, Staff-Captain Smirnov, of the Fortress Sapper Company, had begun a trench low down the front slope of Visokaya. On the left it had been excavated deep enough to allow of firing in the kneeling position, but on the right it was only marked out. In addition to this trench, Smirnov intended to put a battery for two 6-inch guns on the right peak, and, as the surface of the hill near the summit consisted of an almost naked slope of quartz, he hired Chinamen to collect earth at the foot and carry it up the hill in baskets on small donkeys. But, though fifty men were thus employed daily, the work made little progress.

When Colonel Tretyakov took over charge, he reconnoitered the hill with Captain Stempnevski I., Staff-Captain Belozerov, Lieutenant Gleb-Koshanski, and other officers of his regiment, and decided that Captain Smirnov's trench was useless, as it was too wide, had no traverses, and was placed so low down the hill that it was commanded by several hills which were considerably lower than Visokaya. It was therefore decided to make a new trench considerably higher up, and to use the old trench as an obstacle.

The Second and Fourth Companies, Fifth Regiment, were detailed as working parties, and these formed the original garrison of the hill. Captain Stempnevski I., of the Second Company, was made commandant. Henceforth the work proceeded briskly, the men working with pick, crowbar, and shovel each day, from 6 to 11.30 a. m., and after dinner from 2 to 7 p. m. Stempnevski I. was the first to reach the hill each day and the last to leave it at night, and after the 2d of August he stayed there altogether.

Colonel Tretyakov, when riding round his section once and often twice a day, usually spent a long time on Visokaya Hill and paid special attention to its fortification. General Kondratenko also came there fairly often, and was well pleased with the rapidity and excellence of the work. The advice and directions of these senior officers were keenly and skilfully applied by Stempnevski I. The

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1. Visokaya Hill.
2. Flat Hill.
3. Stony Redoubt.
4. False Hill.
5. Nameless Hill.
6. Dug-outs for the companies occupying left flank of flat hill and saddle.
7. Dead ground.

CONVENTIONAL SIGNS

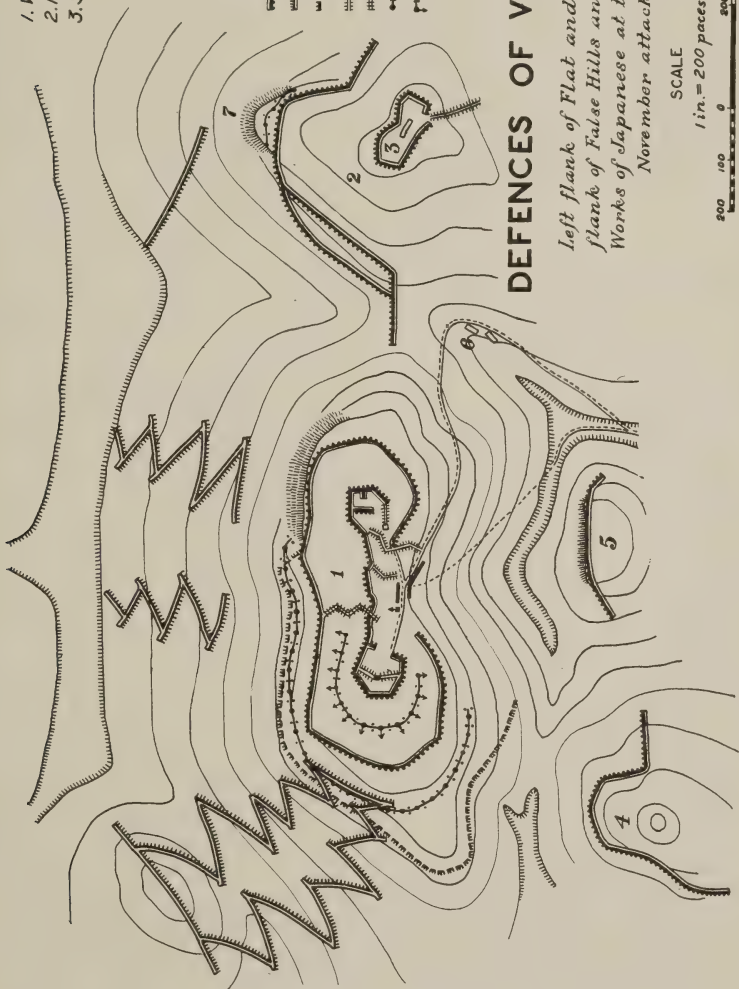
- | | |
|---|----------|
| Trenches | Russian |
| | Japanese |
| Capt. Smirnov's trench, filled in after September attack. | |
| Communication trenches. | |
| Covered ditto. | |
| Wire entanglement. | |
| Ditto and abatis. | |

DEFENCES OF VISOKAYA

Left flank of Flat and right flank of False Hills and Siege Works of Japanese at time of November attack.

SCALE

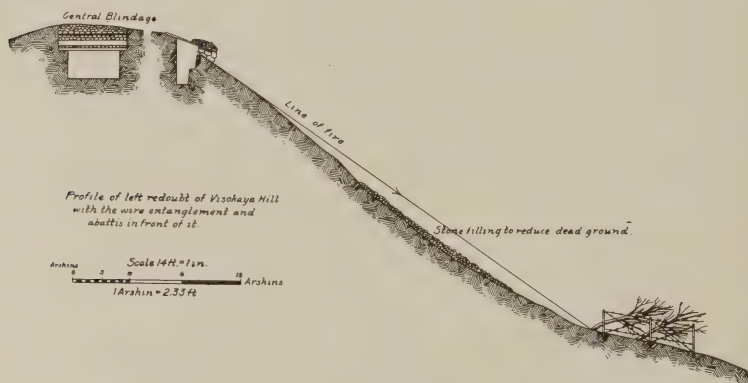
1 in. = 200 paces.



men worked unceasingly on holidays and working days, in spite of rain, heat, and weariness, and by August had completed the following works:

(i.) A ring trench, 3,500 feet in length, of a profile suitable for firing standing in the bottom of the trench, with traverses, strong blindages, and hoods in many places. Owing to the great steepness of the hill, it was found that a parapet would render it impossible to sweep the slopes with fire, and would help to form dead ground. At first, one was made, but later on it was removed and the trench excavated deeper. Some idea of the difficulty of this work can be formed when it is understood that it was all excavated with pick, crowbar, and shovel only.

(ii.) On the left flank, between Visokaya and False hills, Captain Smirnov's lower trench was converted into a ditch of considerable width and depth; but the rest of it, for want of labor and time, was simply brought under fire from the upper trench by ramping its rear slope, so that the enemy could not take cover in it.



(iii.) On the right peak the battery was completed and armed with two 6-inch guns.

(iv.) On the saddle a battery was made for two field guns.

(v.) On the reverse slope of the right flank (heavy gun) battery a magazine was excavated.

The artillery on Visokaya Hill was used only in August. At this time the field guns were so overpowered by Japanese shells that they had to be removed, and were seen no more on Visokaya Hill. Of the 6-inch guns, one was put out of action and the other had its carriage damaged, but they were not taken away, although they were of no use on Visokaya (for they could only fire at long ranges), as this would have required many men for whom more useful work could be found elsewhere. And so they were left on the hill, and even in their damaged state are said to have fired a few rounds in the September fighting.

After August the fortifications were improved, blindages and hoods were strengthened, and fresh ones were made. (See Figs. 1 and 2.)

From the 19th to the 22d of September the Japanese assaulted Visokaya and Long hills; they took the latter, but were repulsed from Visokaya with enormous losses. The steep slopes of the hill were thickly strewn with Japanese corpses, and it took five or six nights to gather in the slain. Some of the

corpses, which are said to have numbered 1,761, were carried down the reverse slope for burial, and with the rest they filled Smirnov's trench, which they afterwards covered up with earth.

The September fighting revealed certain faults in the blindages and hoods. The latter had too large loopholes, so that in some cases men using them were even struck by shrapnel bullets. The blindages were not really proof against the shells of field guns, while 6-inch shells completely destroyed one and seriously damaged four others.

This experience was made good use of, and by November the blindages were

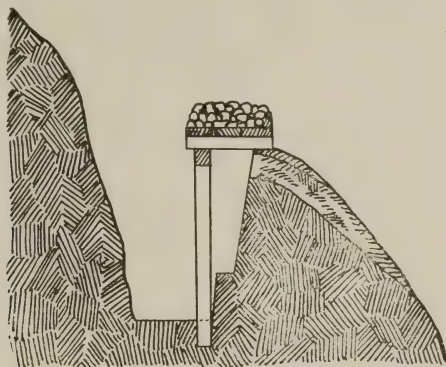


Fig. 1—Original Hood.



Fig. 2—Original Blindage.

greatly strengthened. Each crossbeam was propped in the middle with an 8-inch upright (see Fig. 3), and on the roofs were laid steel plates, about one-half inch in thickness, which were obtained by the sailors, or a row of rails laid flat, and in two or three cases a double row of rails laid upright. Above this was placed a layer of stones from 14 to 28 inches in thickness. Thus strengthened, the blindages were proof against 6-inch and even against Shimoze shells.

The hoods were also improved (see Fig. 4), so that the men could no longer be struck by shrapnel bullets through the loopholes.

The September fighting also showed the necessity of fortifying the left peak

with a redoubt. In spite of the fact that this peak consisted of a smooth rocky slope, yet by November a strong redoubt had been excavated there, with a trench 7 feet deep and 42 inches wide, provided with traverses and blindages, of which a specially strong one was provided in the center for the commandant. The roof of this blindage was protected by a double layer of rails and 42 inches of stones, and, apparently, it was not wrecked even by 11-inch shells. Communication trenches led into this blindage from both sides.

The battery on the right peak was also converted into a redoubt, and was connected with the left peak by a trench, in depth equal to a man's height. This trench passed through the field gun battery, and here its profile was made suitable for firing, standing, from a step.

The ring trench was also strengthened to this profile. Around the ring trench, at a distance of from 20 to 60 paces, according to the ground, was made a wire entanglement, and another was made above the ring trench, at from 15 to 20 paces in front of the left redoubt. Each was about 14 feet in width, but the upper one was further strengthened by abattis, which was brought up from the original position, which lay between Forts Nos. 4 and 5.

For use in bringing up reinforcements, and thus reducing losses, the following communication trenches, which varied in depth from 6 to 7 feet, were excavated: Two to the trench connecting the two peaks, one from the trench in the right battery toward the magazine, and one, blinded, from the connecting trench to the front part of the ring trench.

By November the garrison of Visokaya Hill consisted of the Second, Fourth, and Sixth Companies of the Fifth Regiment, the Seventh Company, Fourteenth Regiment, and the Fourth Company, Fifteenth Regiment. One company was given a rest each day.

Work went on uninterruptedly, and especially by night. Some of the men were employed in dragging up the hill beams, joists, planks, rails, steel plates, bags, etc.; others not only carved the rock with picks, crowbars, and shovels, but also blasted it out with *rak-a-rok*, which greatly helped on the work. A special sapper officer was detailed to superintend.

General Tretyakov, as before, visited the hill daily, and sometimes twice a day. He chiefly gave advice and orders for carrying out fresh work. Other senior officers also came, notably Generals Irman and Kondratenko. During October and November, Colonel Dubitski, the engineer, also came. All gave valuable advice, and Colonel Dubitski also usefully accelerated the delivery of building materials and tools.

As the garrison of the hill could not supply sufficient men to cope with this tremendous work, parties were daily sent from certain companies in the reserve, and when none of these were available, men were brought from the less important posts, and sometimes even from False Hill.

As an example of the care with which the command on Visokaya Hill was managed, it may be mentioned that water for the positions was drawn from a well at the headquarters of the Fifth Regiment, and was transported by night in barrels, and in other parts was carried up the hills in buckets arranged for that purpose. But at Visokaya a steam pumping plant was installed, by which the water brought up in barrels was driven up the hill.

Several men of the garrison, finding how rapidly the rock could be excavated with *rak-a-rok*, set to work to excavate for themselves caves in the rock. One

of the best caves belonged to Staff-Captain Olander, commanding the Fourth Company, Fifth Regiment. Excavated at the bottom of the rear side of the trench, this cave formed a long narrow room, in height equal to the height of a man. The electricians also had a cave, and also some of the sergeant-majors, while others were made in several blindages.



Fig.3-Improved Blindage.



Fig.4-Improved Hood.

The 11-inch shells were unable to wreck these caves, but could and did block up their entrances.

These caves showed that it is possible to excavate in a hill not only roomy and safe shelters for supports, but also tunnels leading to threatened points. Between June and November there would have been plenty of time to do this, but, unfortunately, the *rak-a-rok* was thought of too late.

II. WORKS ON FALSE, FLAT, AND DIVISION HILLS AND THE ORIGINAL POSITION

False Hill, which had been entrenched by its own garrison since May, stood to the left and somewhat behind Visokaya. At the time of the August fighting its works consisted of shallow trenches, and on its summit had been placed two spars, the tarred ends of which projected outwards, and were intended to look like the muzzles of guns. It was hoped by this means to deceive the enemy and make them uncertain as to whether the firing was carried on from here or from Visokaya, and from these false guns the hill received its name.

During the September attack, this hill brought a flanking fire to bear upon the Japanese and contributed largely to their repulse.

By November its works took the form of a redoubt, with profile for firing, standing, from a step provided with traverses and blindages. The blindages were practically the same as those on Visokaya had been in September. Warming places were provided at intervals in the rear slope of the trenches.

The works on Intermediate Hill were of equal strength to those on False Hill, and were shaped like a wide lunette—a trench with bent-back flanks.

Flat Hill lay to the right of Visokaya, and was occupied after the fall of Long Hill on the 20th of September. Its defenses were not begun till after this date, but nevertheless by November it had been provided with a trench, on the left flank in two tiers, for firing, standing, from a step with traverses, hoods, and warmed shelters; and on the summit was placed a redoubt, named Stony Redoubt, of similar profile to the trench and provided with traverses and hoods. In the redoubt there were strong blindages for the company and a separate one for the commander. These were made by covering over a trench with two layers of beams and laying about 28 inches thickness of stones on the top.

Flat Hill flanked the approaches to Visokaya, and its preservation was essential to the safety of the latter.

Division Hill (between Flat Hill and Fort No. 4) was so named because it was intended to put a division of field artillery there, and was actually used for this purpose in August, emplacements having been provided meanwhile. By November it was entrenched as strongly as False Hill, but special attention had to be paid to its vulnerability from the left flank, and its trenches were therefore divided into sections, and two subsidiary trenches at right angles to the main ones were provided.

The line of works between the Forts Nos. 4 and 5, *i. e.*, Two-Angled and New lunettes, Fougasse Knoll, Red Hill, etc., are called the "original position," because up to May, 1904, it was the only line prepared for defense in this section. It was made by the engineers probably at the same time as the forts, and as a position was far from satisfactory, either from a tactical or from a fortification point of view. It was protected by trenches of profiles in places suitable for firing, standing, from steps and in places for standing in the bottom of the trench, with traverses only in places and light blindages.

In all the defenses the firing positions were provided with loopholes under the hoods. So long as the Japanese remained at a distance, these loopholes were satisfactory, but by October, as the Japanese advanced their saps, the 8 to 10 inch openings became dangerous, and many men using them received fatal wounds in the head. This was afterwards counteracted by hanging curtains behind the loopholes and raising them cautiously when the latter were occupied for firing.

One day the troops returning from a successful sortie brought back a Japanese loophole plate, made of one-half-inch steel, with a cross-shaped opening in the middle for convenience of aiming and firing.

At the request of General Tretyakov, Colonel Dubitski prepared some plates of slightly modified design for the Russian trenches. These plates were rectangular, $8\frac{3}{4}$ inches in height, and a little less in base measurement, while the vertical slots in the cross-shaped openings were made somewhat longer than in the Japanese plates, to give greater freedom in firing down the steep slopes of the hills. In all, 100 of these plates were supplied, of which 75 were allotted to Visokaya and 25 to Division Hill.

The fact that the openings on these plates were very difficult to hit induced greater steadiness in those using these loopholes. The men also took to protecting the loopholes for which there were no plates with stones. By this means the size of the loopholes was reduced, but not to the same extent as with the loophole plates.

Previous to the September attacks a mining apparatus had been established on Visokaya, but it proved useless, as it was put out of action by the first shells, and was afterwards taken away.

There were four machine guns on Visokaya and two more on Flat Hill. The mountings were found to be very bulky and inconvenient, and the men threw them away and rested the guns directly on the parapet. This not proving quite satisfactory, a trough was designed by Ensign Ermakov, from which the guns worked splendidly. All the same, the machine guns on Visokaya were of little effect, as they were all put out of action by the 29th of November, and took no part in repelling the final attacks.

After their ill-success in September, the Japanese advanced against Visokaya Hill (in every sense a *field* fortification) by patient sapping, and by the time of the November assaults had obtained the following results:

(1.) A sap, with two heads, on the left flank of Visokaya, clearing the wire entanglement, had arrived within 30 paces of the ring trench, and ended in a parallel.

(2.) A sap in the center had arrived within 150 to 200 paces of the ring trench.

(3.) A sap on the right flank of Visokaya had arrived within 150 to 200 paces of the ring trench, and ended in dead ground, formed by the steepness of the hill at this point. From here the Japanese could get to the trench safely, but to reach it they had with great difficulty to scale the almost perpendicular cliff. This dead ground proved very treacherous to the Russians.

And, lastly (4), a branch from this last sap came within 150 to 200 paces of the trenches on Flat Hill.

A sap was also driven against the left flank of Division Hill, but as this attack was not pressed it is unimportant.

III. GARRISON AND COMMAND

The garrison of Port Arthur consisted of the following units:

Fifth East Siberian Rifle Regiment (detached from the Fourth East Siberian Rifle Division) of 11 companies (the Twelfth formed part of the Consular Guard in Pekin), and mounted volunteer detachments.

Fourth East Siberian Rifle Division, commanded by Lieutenant-General Fok,

Thirteenth, Fourteenth, Fifteenth, and Sixteenth East Siberian Rifle Regiments, each of 12 companies, and 1 mounted volunteer detachment.

Seventh East Siberian Rifle Division, commanded by Major-General Kondratenko, Twenty-fifth, Twenty-sixth, Twenty-seventh, and Twenty-eighth East Siberian Rifle Regiments, each of 12 companies.

Third East Siberian Rifle Reserve Battalion, 4 companies.

Fourth East Siberian Rifle Reserve Battalion, 4 companies.

Seventh East Siberian Rifle Reserve Battalion, 4 companies.

At the beginning of the war each regiment was made up with reservists to approximately 3,000 men. As the companies were considered overcrowded, it was decided to separate out the volunteer detachments, to form one, two, or three *foot* volunteer detachments, according to the number of battalions in each regiment.

A sotnia of the First Upper Udinsk Cossack Regiment.

Fourth East Siberian Rifled Artillery Brigade, 4 8-gun batteries.

Seventh East Siberian Rifled Artillery Brigade, 3 8-gun batteries and fortress artillery.

The commander-in-chief at Port Arthur was General Stessel, commandant of the Kwantung fortified rayon. His second in command was Lieutenant-General Smirnov.

The defense of Port Arthur was divided into two main sections, sea and land. The latter was entrusted to General Kondratenko.

The line of land defense was divided into three parts: 1, the Eastern Front (right flank); 2, Northern Front (center); and 3, Western Front (left flank), from Fort No. 4 to Pigeon Bay, inclusive. The commander of the Western Front was Colonel Irman, commanding Fourth East Siberian Rifled Artillery Brigade. His section was divided into divisions, and the commander of the First Division was Colonel Tretyakov, commandant of the Fifth Regiment. Colonels Irman and Tretyakov were of equal rank, Tretyakov being senior as a colonel and Irman senior as a brigadier. Both were promoted major-generals in October, 1904, but they were unaware of the fact, and earned their fame in this fighting as colonels, and not as generals.

In the First Division were included the following positions:

1. Fort No. 5.
2. The line of trenches in the Original Position between Forts Nos. 4 and 5.
3. Everything in rear of this as far as the New Town.
4. The Jagged Hills lying to the front, of which in November there were occupied: Division Hill, Flat Hill, Visokaya, False, and Intermediate hills, each of which had its separate garrison and commandant immediately under the orders of General Tretyakov.

The staffs were designated as follows:

General Stessel's Staff, the Rayon Staff; General Smirnov's Staff, the Fortress Staff; General Kondratenko's Staff, the Land Front Staff; General Irman's Staff and General Tretyakov's Staff, the Fifth Regiment Staff.

This last staff was located in the Tea Ravine, in rear of Fougasse Knoll. The rest lived in the town.

Urgent reports and orders were sent by telephone. The Fifth Regiment Staff had four telephones: 1, to Fort No. 4 and Entrenchment No. 4; 2, to the town;

3, to the positions on Visokaya, False, Flat, and Division hills; and 4, wandering.

For discipline, the Fifth Regiment was under the orders of Generals Irman and Tretyakov, but for supply it was under General Fok, as commandant of the division to which the regiment was attached. This led to considerable inconvenience.

The first commandant of Visokaya, as already mentioned, was Captain Stanislaw Julianovich Stempnevski I., commanding Second Company, a man in the highest degree hardworking, painstaking, and brave. His service on Visokaya Hill presented a continuous round of courage, hard work, and privation. His work was repeatedly noticed in orders during August and September by Generals Kondratenko, Irman, and Stessel.

Visokaya Hill, as already mentioned, was a most important position and required a commandant who should be always on the *qui vive*, always prepared to resist the enemy. Such tension, combined with the constant danger and anxiety over the fortifying and guarding of the hill, greatly affected the commandant, especially during the fighting. In consequence of this, and although he knew him to be always brave, energetic, and cool-headed, General Kondratenko decided to appoint a second officer, who should share the command with Stempnevski, each holding it in turn for a period of forty-eight hours.

The Fifth Regiment always did their best to merit the special consideration and trust which General Kondratenko placed in it, and which the dead hero repeatedly expressed to the regiment, and of which the latter was very proud. Referring to the choice of a second commandant of Visokaya Hill, he said: "I wish both commandants and not less than half of the garrison to be from the Fifth Regiment." Though he well knew that in the preceding battles the regiment had lost more than thirty officers, killed or died of wounds, that the companies were all commanded by lieutenants, sub-lieutenants, and even ensigns, and that, consequently, there was no great choice, and though he recognized the inconvenience of subordinating commanders of companies which came to join the garrison of the hill, sometimes gray-haired captains of other regiments, to a commandant of half their seniority from among the company commanders of the Fifth Regiment, yet General Kondratenko remained firm in his opinion and repeated: "The Fifth Regiment are all heroes! I demand that both commandants and not less than half the garrison shall be of the Fifth Regiment. Then I shall be content."

At first Captain Stempnevski I. was relieved by Staff-Captain Sichev, commanding the Sixth Company, during the September fighting. After two days' struggle, the Second Company (Stempnevski's) had lost three-quarters of its strength and presented a mere handful of exhausted men, half of them wounded, and urgently requiring relief and rest. While considering the men, it was impossible to overlook their commander. The Sixth Company was sent up, and their commander, Sichev, took up the command of the hill. The Japanese were repulsed, and Sichev was decorated with the Fourth Class of the Order of St. George.

From the 21st of September to the 29th of October the relief of commandants was carried out regularly every two days.

Having taken up the command on the latter date, on the 31st of October Stempnevski refused to be relieved until the Japanese, who were attacking the

hill on that day and the day before, should finally leave the place. The reason for this refusal was that in the previous fighting Stempnevski I. had been on the hill and had taken an active part in repulsing the Japanese, and together with Sichev had been recommended for a decoration. But General Fok had struck out his name, probably because he had been relieved during the fighting. Stempnevski was much hurt, and looked forward to the next attack on the hill to prove himself worthy of this high reward.

On hearing of his resolve, General Tretyakov informed him by telephone that he never doubted his courage, and that this was confirmed by his nomination as commandant of the hill, and that his resolve would be reported to the proper quarter.

On the 1st of November Sichev was wounded, although only slightly, by splinters of a shell which burst in the New Town, and was unable to relieve Stempnevski. In his place there was detailed an exceedingly gallant officer, Staff-Captain Belozerov, commanding the Third Company, who had gained distinction in the previous fighting for courage and presence of mind. Thus in the retirement from Kinchow, while moving by night through a narrow gorge in the Mid-Arthur road, disorder arose in the baggage train from the unfounded rumor that the Japanese cavalry were following in pursuit. At the same time the inhabitants of Dalny began to join the column, bringing their possessions in Chinese carts. The more panic-stricken of these, trying to push forward in the narrow road, began falling down themselves and knocking down others, so that the whole convoy would have been rapidly in disorder had not its commandant, Belozerov, worked with a will, with voice and whip, and sparing none, rapidly restored order.

In the fighting on Angle Hill, on the 19th and 20th of August, he again distinguished himself. His Third Company lost 70 per cent of its strength in repulsing the furious attacks of the Japanese, and he himself was always in the post of danger urging on his men. On the 20th of August, having been nominated commandant of that hill, in the place of the wounded Colonel Lisaevski, he personally several times led the reinforcements in counter-attack, repulsing an enemy ten times his strength, until he was wounded in the chest by a shrapnel bullet. Within little more than a month he was convalescent and again at the head of his company, then posted on Division Hill.

Generals Kondratenko, Irman, and Tretyakov, who had witnessed the fighting at Angle Hill, offered Belozerov the honorable post of joint-commandant of Visokaya Hill, which he willingly accepted.

At the beginning of the fighting the garrison of Visokaya consisted of the following:

Fifth Regiment: Second Company, 98 men; Fourth Company, 103 men; Sixth Company, 121 men.

Fourteenth Regiment: Seventh Company, 108 men.

Fifteenth Regiment: Fourth Company, 174 men.

Machine gun detachment (sailors).

Detachment of the Kwangtung Sapper Company.

One company was withdrawn for rest every two days. At the time of the fighting, the Seventh Company, Fourteenth Regiment, was resting.

The garrison of False Hill consisted of the following:

Fifth Regiment: Eighth Company, 138 men; Eleventh Company, 148 men.

The commandant of False Hill, appointed in August, was Staff-Captain Marchenko.

The garrison of Division Hill consisted of the following:

Fifth Regiment: Third Company, 137 men; Fifth Company, 89 men; Seventh Company, 182 men; portions of Second and Third Foot Volunteer Detachments, 93 men.

Fifteenth Regiment: Fifth Company, 96 men.

Twenty-seventh Regiment: Ninth Company, 133 men.

As commandant, Captain Stempnevski II. was appointed in August.

The garrison of Flat Hill consisted of the following:

Fifth Regiment: Ninth Company, 152 men; Tenth Company, 152 men.

Twenty-seventh Regiment: Fourth Company, 108 men; Fifth Company, 138 men; Eighth Company, 118 men; Eleventh Company, 128 men; Composite Company, 148 men; Volunteer Detachment, 91 men.

From October the commandant of Flat Hill was Lieutenant-Colonel Budyanski, Twenty-seventh Regiment.

Intermediate Hill was occupied by Tenth Company, Twenty-sixth Regiment, more than 160 men, and its commander, Staff-Captain Lax, was commandant.

The original position was occupied only during the fighting, and at other times was protected only by guards, who were posted in two places, on roads.

The following troops remained in reserve with the Staff of Fifth Regiment, in the Artillery Barracks in Tea-House Ravine:

Fifth Regiment, Twelfth Company, 112 men.

The Seventh Company, Fourteenth Regiment, was resting, and with the colors of Fifth Regiment was one section, Eleventh Company, 22 men.

IV. CAUSES WHICH OBLIGED THE JAPANESE TO PERSIST IN ATTACKING VISOKAYA HILL

At the end of October the squadrons of Admirals Rozhdestvenski and Nobogatov were approaching Madagaskar, with a view to uniting and together moving into the waters of the Pacific.

This circumstance caused alarm among the Japanese, because the approaching Baltic squadrons, combined with the remaining uninjured ships of the Port Arthur and Vladivostok squadrons, would present a formidable strength. Therefore the Japanese Naval Administration urged the army besieging Port Arthur to take it without delay, or, at any rate, to seize positions from which they could destroy the fleet which was taking shelter there.

In November this urgency became so insistent that the army of General Nogi received a definite order to advance to the attack, in spite of the incompleteness of its preparations.

In addition to the three infantry divisions and the two detached infantry brigades which had hitherto been before Port Arthur, in October the Tenth Brigade, composed of men of the second call, arrived from Japan, and about the middle of November the Seventh Infantry Division, which had as yet seen no service, began to disembark at Dalny.

An English correspondent, at that time with the Japanese before Port Arthur, writes of this division that it was composed of young fresh troops recruited in the Island of Hokkaido, and reputed the best and bravest of the whole Japanese

army. Their arrival brought the strength of the besieging army up to close upon 100,000 men, including twenty-four infantry regiments.

With this force General Nogi again tried to take Port Arthur by assault, and on the 26th of November, after several days' bombardment, the Japanese attack was carried out on the region of Forts Nos. 2 and 3.

Besides warning each soldier in this attack that he must be prepared to go to certain death for the attainment of the common object, the following is an example of the orders issued by the Japanese commanders:

"Order of General Nakamura to a party of 2,000 volunteers who had engaged as a forlorn hope to work down the Lunho Valley:

"The object of our detachment is to cut in two the Port Arthur defenses. Not a man must hope to return alive. If I fall, Colonel Vatanabe will take my place; if he shares the same fate, the command will pass to Lieutenant-Colonel Okuno. Every officer, whatever his rank, must appoint himself his successor. The fighting will be carried out chiefly with the bayonet. However murderous the enemy's fire, our men must not reply with a single shot until we are established in their lines. The officers are permitted to slay any men who, without cause, straggle, leave the ranks, or fall back." The story of the failure of this gallant party is well known and need not be repeated here.

In the course of fifteen hours' continuous fighting the Japanese lost 10,000 men and failed to obtain the smallest success; not a trench was lost. From this they learned that the hour had not yet come for the fall of these forts, and gave up hope in the early capture of Port Arthur.

On previous occasions, after their unsuccessful attacks, they had usually spent three or four weeks in preparation for a new attack; but in this case they were obliged to carry forward the attack without delay. The orders from Tokyo were peremptory, and Generals Fukushima and Kodama were sent by Marshal Oyama, the commander-in-chief of the Japanese armies, to the headquarters of the besieging force to see that they were carried out.

And therefore, after giving up hope of the early fall of the fortress, General Nogi was obliged to push forward assaults with the object of capturing positions from which he could destroy the Russian fleet.

As Visokaya Hill was, if not the only, at any rate the most suitable position for carrying out this object, it forthwith attracted all the fire, the attention, energy, and the main forces of the Japanese.

V. FIGHTING FROM THE 25TH OF NOVEMBER TO THE 5TH OF DECEMBER

During this period the weather was settled, the days almost always bright and cool, with the wind blowing generally from the southwest, and the nights dark and cold (from 3° to 5° R.).

On the 25th of November the Japanese on the western front were largely reinforced, especially in front of the section commanded by Captain Romanovski, where they pressed in the Russian mounted parties and tried to break through them, but were stopped by the timely arrival of reinforcements and the skilful and successful dispositions of Captain Romanovski.

In the night of the 25th-26th of November a Japanese force of not less than a battalion of infantry concentrated near Pigeon Bay, in front of a position held by Staff-Captain Soloviev, with a composite company of the Eleventh and

Twelfth Regiments (collected from the depot of these regiments, which was in Port Arthur) and the foot volunteer party of the Twenty-eighth Regiment, under Lieutenant Mikheev, in all, about 300 men, and forthwith attacked it.

It should be mentioned that the repulse of the September attacks was greatly assisted by the action of a section of field artillery under Staff-Captain Yasenski, which moved out from the direction of Pigeon Bay and, by its unexpected and well-aimed fire, dispersed about a brigade of reserves at the foot of Visokaya Hill. To prevent this occurring again, the Japanese hoped to take the position at Pigeon Bay before again attacking Visokaya.

After a desperate struggle, the Japanese, at about 3 a. m. on the morning of the 26th, succeeded in breaking through and capturing the most forward knoll; but the attack on the main position was repulsed with grenades and rifle fire. The artillery from Lieutenant Erofeev's position assisted in obtaining this result.

In the hope of driving the Japanese from the front knoll, Staff-Captain Soloviev at dawn carried out a counter-attack, in which he was killed; but the knoll remained in the hands of the Japanese.

VI. FIGHTING ON VISOKAYA AND FLAT HILLS

On the 26th of November, from 10 a. m. till evening, the Japanese shelled Visokaya, and fired in that interval 25 11-inch shells, 80 6-inch, 60 mines, and 300 other shells of small caliber from field guns, mountain guns, etc.; the bombardment caused a great amount of damage.

General Tretyakov during the day watched the fighting on the right flank and center, and from what he saw concluded that the Japanese were transferring the attack to the left flank, and toward evening he passed the following order along the position: "I am expecting an attack on our positions. Let everything be in readiness to offer due resistance.—Colonel Tretyakov." The companies of the reserve were ordered to stand by in readiness near the Fifth Regiment headquarters, and the trenches of the second line, *i. e.*, those lying between Forts Nos. 4 and 5 (Red Hill, Fougasse, Two-Angled, and New lunettes), were occupied by the companies of non-combatants allotted to this section, *i. e.*, those of the Fifth, Thirteenth, and Twenty-eighth Regiments.

The reason that the non-combatants were ordered to occupy positions was because even during the earliest fighting at Port Arthur it was felt that the garrison was too weak in numbers. To make up the deficiency the corps of Port Arthur Foot Town Guards was formed, but as even then numbers were insufficient, after the sanguinary fighting in August and September, General Stessel ordered all non-combatant establishments to be reduced to a minimum and all men thus saved to be sent to the positions. In consequence of this, not only the staffs of clerks, bakers, and other specialists were reduced by about one-half, but even in each of the officers' messes only three men were left, and those preferably men who had recently come out of hospital after having been seriously wounded.

Officers' private servants were also reduced and replaced by wounded men, and the men of the bearer companies, required for carrying the wounded, were replaced by the remainder of the clerks and musicians. In a word, Gen. Stessel arranged that during the fighting not a man should be wasted. But in spite of this an insufficiency of fighting men was experienced. Then he went further

and ordered that all non-combatants, except the drivers in charge of the traveling kitchens and the ammunition carts, must go to the positions. This measure supplied about 1,000 fighting men, but as on their departure all regimental routine was at a standstill, he further ordered that when no attack was either going on or immediately expected, these non-combatants were to carry on their usual work.

In case of need they had to come up at the first call, and as General Tretyakov summoned his non-combatants into position, it is evident that he had no doubt that his section was about to be attacked. And so it was.

The Japanese kept up a steady rifle and artillery fire on Soloviev's position all day and all night, in the hopes of drawing off attention and reserves from Visokaya Hill.

On the 26th of November, from 9 a. m. till evening, they kept up a heavy fire on Visokaya, and expended about 800 11-inch shells, 300 6-inch shells, 20 mines, and more than 1,000 smaller shells.

On this day the Japanese artillery directed all their fire on the redoubts excavated in the rock on the two summits of the hill. The redoubts were much damaged; in places the 11-inch shells cut off great masses of granite half the size of a cottage, which fell down and in places completely blocked the trenches; but as the infantry was in the ring trench, and the redoubts during the bombardment were occupied only by sentries, the losses were very small in comparison with the number of shells fired.

Toward evening General Tretyakov, expecting an attack, sent the Seventh Company, Fourteenth Regiment, to reinforce Visokaya Hill, and the Twelfth Company, Fifth Regiment, to Flat Hill; but both companies eventually went to Flat Hill, as by the time they came up it was evident that they were more needed there.

At 5 p. m. the Japanese infantry attacked Visokaya, but were repulsed. At the same time they attacked Flat Hill, and here they were at first successful, driving out the remnants of the Fifth Company, Twenty-seventh Regiment; pressing on to the Stony Redoubt, they had even burst into it, when the reinforcing companies came up in time and beat them out.

In this struggle the Fourth Section, Seventh Company, Fourteenth Regiment, under Sergeant Loshkarev, especially distinguished itself. Arriving with the rest of the company at Flat Hill, this non-commissioned officer got leave to lead forward his section against the Japanese, who had got into the Stony Redoubt and were collected there in bunches, uncertain what to do next and probably waiting to be reorganized.

This gallant section, without waiting for the Japanese to recover themselves, charged into them with the bayonet. They lost their heads and rushed back, practically offering no opposition. The remainder of the company then came up, followed by the Twelfth Company, Fifth Regiment, under Lieutenant Ivanov, and drove the Japanese from the lower trenches also.

About 6 p. m., just as the Japanese had broken into the redoubt, one of the columns driven back from Visokaya attempted to seize the saddle between Visokaya and Flat hills; information was sent forthwith by telephone to the batteries, which immediately opened a heavy fire on the column. At the same time rifle fire was brought to bear upon it from Visokaya. Entrenchment No. 4 was the first to open an especially successful fire on this column. Under this com-

bined fire the column fell back, but in the darkness it was difficult to estimate its losses.

In the center of Flat Hill the Japanese also had some success, but were driven back by half of the Ninth Company, Fifth Regiment.

By 8.45 p. m. the Russians were everywhere reestablished in their original positions, and while some engaged in a hand-grenade fight with the Japanese, others repaired their damaged works.

The riflemen who took part in this fighting, when they considered the undecided action of the Japanese in the captured redoubt, so different from their usual ready way of adapting themselves to circumstances and their previous stout resistance to counter-attacks, decided that they must have been recruits. It was also noticed that the few wounded Japanese who were captured were young-looking men. These appearances led to a rumor that the Japanese were nearing the end of their resources, and in order to replace their enormous losses had to draw upon untrained recruits and youths of eighteen and nineteen.

In the evening the non-combatant company, Fifth Regiment (81 men), was sent to Flat Hill; the Twelfth Company, Fifth Regiment, took over on Flat Hill part of the trenches of the Fifth Company, Twenty-seventh Regiment.

At about 6 p. m., in the thick of the fighting on Flat Hill, several alarming telegrams came in. From Division Hill it was reported that fully a company of the enemy were lying under the slope near the Third Company trenches, and that opposite the left flank of Division Hill the Japanese were coming forward in groups from Dead Knoll. From Flat Hill reports arrived that the Japanese had broken in and the hill was in great danger, and that reinforcements were urgently necessary; and from Visokaya that the enemy's columns were moving between Visokaya and Flat Hills.

Among the others, the following message was received: "To-morrow, by order of General Fok, General Nedein and I are coming to inspect the biscuit store of the Fifth Regiment.—Staff Captain Shelkovnikov." In spite of the want of consideration on the part of the commander of the Fourth East Siberian Division, which this message, sent at such a time, displayed, General Tretyakov found time to make suitable arrangements, and on the following day the supply officer, Staff-Captain Felitsin, commanding the non-combatant company, with the quartermaster, Lieutenant Frost, and a few drivers—the rest of the non-combatants being then on Flat Hill—were taken away from their work for several hours.

On the 27th General Irman ordered, by telephone, Captain Romanovski, commanding the Second Division of the West Front of the Land Defense, to send the section of quick-firing artillery, commanded by Lieutenant Siromyatnikov (Second Battery, Fourth East Siberian Rifled Artillery Brigade), from Lyaoteshan to a position at the village Liudzyatun, near Pigeon Bay, with the object of sweeping with fire the southern and western slopes of Visokaya, and thus striking the Japanese attacking columns in flank and rear.

The General sent a special message to this officer that he must assist the defenders of Visokaya Hill by every means in his power, and that their chief hope lay in him.

In two hours, *i. e.*, between 3 and 5 a. m., November 28, Lieutenant Siromyatnikov brought his two guns into position behind a low hill, which successfully concealed them from the enemy's view, without impeding their fire by its

sloping sides. A gently sloping rise in rear of the guns blended imperceptibly with the foreground, and thus masked them from Japanese detection. Firing began at dawn, but was penalized by the bad quality of the fuzes, which frequently failed to burst the shells.

The observation post was skilfully selected on the crest of the hill in front and to the left of the guns, and, masked by Chinese tombs, the observers got a good view of Visokaya Hill and the approaches to it from the enemy's side. They remained continually on the alert, and when the Japanese advanced they promptly opened fire on them.

A few well-aimed shells compelled the Japanese to disperse and take cover in their approaches, where these guns, which were equipped with nothing but shrapnel, were unable to touch them. In the evening they were reinforced by another section, under Staff-Captain Nezhentsov, but unfortunately the limited supply of shells prevented their fire from being developed as much as the occasion demanded.

These guns kept up their fire by night, using as a stationary directing object the Lyaoteshan Lighthouse, which was situated about 5 versts in rear of the position. The Japanese did not direct any serious fire in their direction, but from the occasional common shell which fell in their vicinity it appeared that they were searching for their position.

With a view to diverting attention from Visokaya Hill and depriving the Russians of a position which commanded their approaches to that point, the Japanese before dawn advanced once more against Soloviev's position; but after three attacks had failed, at about 5 a. m. they desisted, and contented themselves with shelling the Pigeon Bay defenses.

November 28th, the Japanese continued the whole night shelling Visokaya and Flat hills, and although their fire was weaker than it had been during the day, yet the damage done exceeded in extent the repairs which the defenders managed to carry out. At dawn the fire increased, and at that moment they again advanced to the assault. The Fourth Company, Seventh Reserve Battalion, was sent up to Visokaya at 8 a. m., and a composite company of the Third Division (71 men) at 8.20. So impetuously did the Japanese press the attack that a few men gained the left peak of the hill and there posted a flag, but owing to the timely arrival of reinforcements the attack was repulsed, the gallant men who had reached the crest were slain, and the flag thrown down. After this the Japanese began collecting under the hill for a fresh attack.

At 10.30 a. m. the non-combatant company, Fifteenth Regiment, was sent to Visokaya Hill, and as no more reserves remained with the staff of Fifth Regiment, General Tretyakov ordered the First Company, Seventh Reserve Battalion (Staff-Captain Diukin, 89 men), which had just been sent as a reinforcement to Flat Hill, to go over to Visokaya. This shows clearly how urgent was the need of reinforcements.

Meanwhile the Japanese maintained a strong artillery fire, which caused enormous losses. About 11 they carried out a fresh attack, but owing to the timely arrival of reinforcements it was also repulsed. About 11.40 the artillery fire ceased, their infantry went away, and quiet lasted for about an hour. They were probably having their dinners. The Russians sent down urgent messages for food to be sent up to the positions, but owing to want of haste and also to the stocktaking in the biscuit store, no food arrived before

12.30, just as the Japanese reopened their fire, and with such energy that even 11-inch shells fell three or four at once. The men grew fewer and fewer, and all the local reserves were expended in replacing the dead. At 2 p. m. the Sixth Company of the Kwantung Naval Detachment (109 men), under Lieutenant Pashkov, was sent to Visokaya, and a little later the non-combatant company, Fourteenth Regiment (100 men), under Lieutenant Loko-shchenko, and also the non-combatant company, Sixteenth Regiment (121 men), under Lieutenant Yenkovich.

On Flat Hill nothing of importance was happening, but the trenches of the two companies on the left flank (the Fifth and Eighth Companies, Twenty-seventh Regiment) were wrecked and many of the men put out of action. The commandant, Lieutenant-Colonel Budyanski, expecting a night attack, called urgently for reinforcements, but there were none to send; in fact, both General Tretyakov and General Irman received refusals from headquarters to their own pressing and reiterated requests for more men to be sent to them. The Seventh Company, Twenty-seventh Regiment, which came up at about 2 p. m., was at once sent to Flat Hill, and the only reserve which remained with the Fifth Regiment Staff was a half company of sailors, landed from the *Amur* (71 men), who were kept back in case of the enemy breaking in between Flat Hill and Visokaya.

Meanwhile at 3.10 p. m. Captain Stempnevski I., commanding on Visokaya, reported that in the center of that hill all the blindages were wrecked, on the right flank almost all were choked with earth, that many of the men were crowded together and buried in the blindages, and there were no spare hands to assist in digging them out, and in any case this was impossible owing to the fire; the communication trench leading to the center was blocked in two places, and all communication had become very difficult. It was also reported that the losses were enormous and reinforcements very necessary.

At 3.20 p. m. Lieutenant Erofeev, who was observing the front of Visokaya from Pigeon Bay, reported about a company of Japanese lying to the east of some groups of stones under the left peak, and that east of their communication trench dense lines of Japanese were climbing out of their saps, and more still were following them. Evidently they were preparing another attack on the hill. Generals Tretyakov and Irman again urgently begged for reinforcements, but the only answer they got was that there were no reserves left, and that Visokaya Hill was expending such a large number of reinforcements that they must really be more economical.

As soon as, by continuous pounding, the Japanese had thoroughly prepared the way for success, at 4.30 p. m. they advanced up Visokaya Hill in dense masses. The attenuated Russian line had no power to resist them, and they occupied the front, or western, part of the ring trench.

Stempnevski now reported by telephone that the Japanese were crowding into his position in large numbers, that he had not got sufficient men to hold it any longer, and begged for permission to give it up.

General Tretyakov wanted to go up the hill in order himself to take over the superintendence of its defense, but his staff restrained him; whereupon he sent an order to Stempnevski to hold the top at all costs. At the same time the condition of affairs on the hill was reported to the Staff of the Land Defense.

Tretyakov now ordered the Fifth Company, Fifth Regiment, on Division

Hill, to come at once to the Fifth Regiment headquarters, and the Seventh Company, who were alongside them, to spread out into the Fifth Company trenches. General Irman, who had been following the fight on Visokaya with field glasses from Fougasse Hill, now returned to Fifth Regiment headquarters and confirmed Tretyakov's dispositions. He thanked him, and when at 5 p. m. he got into conversation through the telephone with General Kondratenko, he told him that the hill had only been held hitherto by the energy and resourcefulness of General Tretyakov. At the same time he sent the following report to the Fortress Staff: "The Japanese have occupied nearly the whole of Visokaya. The whole of the trench on Flat Hill is in their hands. I am expecting them to break in, and have in reserve only a half company of sailors.—From General Irman; 5 p. m., 28th November."

Both the Land Defense Staff and also General Stessel sent orders to hold Visokaya at all costs.

After this alarm as to the fate of Visokaya had been realized, reinforcements began to arrive in some proportion to the urgency of the case. General Kondratenko, anxious about the hill, came himself at 6 p. m. to the Fifth Regiment headquarters, in order that he might become more closely acquainted with the conditions and give his sage advice.

All met this heroic man with joy, and felt more confident in his presence. By his gracious tone, his kindness, and tranquillity—rare qualities, which did not desert him even for a moment—he was universally welcome.

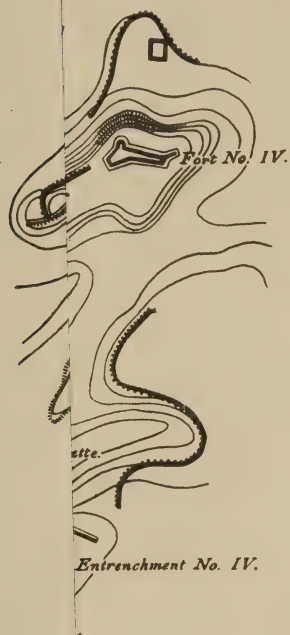
Meanwhile, conditions on Visokaya had become worse and worse. Having established themselves in the ring trench, the Japanese climbed up to the redoubts and on to the saddle. They captured part of the left redoubt, but in the remaining parts, thanks to the vigorous action of Stempnevski, a desperate struggle was maintained.

General Tretyakov, fearful for the fate of the hill, eventually rode up to take immediate charge of the fighting. On the way his horse was wounded in the foot by a rifle bullet fired from the hill, which gives some idea to what extent it was then occupied by the Japanese.

At 9.30 p. m., the following telephone message was received at the Fifth Regiment Staff, and immediately transmitted to Tretyakov on Visokaya: "From General Stessel. To Colonel Tretyakov. I order you to defend Visokaya Hill like Bayazid. It is a most important point."

When Tretyakov on arrival had taken up the direction of the defense and had personally ascertained the state of affairs, he reported: "The trenches on Visokaya are destroyed, the blindages broken, and its maintenance is very difficult. I will do what I can." Then, collecting the newly arrived reinforcements and distributing the men among the various areas, he led them forward to drive the Japanese from the trenches which they had occupied and from the left redoubt.

The following reinforcements reached Visokaya Hill before midnight, but their times of arrival are not accurately known: Fifth Company, Fifth Regiment, 89 men, Captain Fofanov; two companies of seamen from the *Amur*, 20 men; Seventh Company, Seventh Reserve Battalion, Lieutenant Antonov, 44 men; composite company, Twenty-eighth Regiment, Sergeant-Major Kurnosov, 71 men; half of the Eighth Company, Twenty-sixth Regiment, 60 men; and at 2 a. m. on the 29th of November, the Third Company, Naval Battalion



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(from the ironclad *Pobieda*), Midshipmen Bershadski and Fleisher, 171 men.

The first counter-attack was unsuccessful; the companies took the wrong direction and then fell back at 10 p. m.

Just then, another company coming up, General Tretyakov added it to his forces, and again distributed the companies to areas, encouraged them, and personally led them to the attack.

The night was dark; all around were heard the crackling of rifles, the sharp cries now of the Russians and now of the Japanese, the bursts of hand grenades, and the deafening crashes of large and small shells. In the darkness, from time to time, now here, now there, the Russian riflemen lighted up Roman candles, improvised for them by their mining officers.

In this night fighting success sometimes favored one side, sometimes the other. To avoid going into too great detail, it will be sufficient to record here only one important and interesting occurrence.

The reinforcing companies, encouraged by General Tretyakov, moved forward rapidly, but as they approached the Japanese they stopped; cries were heard, disorder spread among them, and the next moment they had broken backwards, carrying away with them the line which had hitherto stood firm. The whole hill was cleared in a moment. The ruin appeared to be irretrievable, and no power could turn the flying men. Near General Tretyakov, among a small group of riflemen and one or two officers, stood Ensign Ermakov, and to him Tretyakov gave orders to run down the hill and turn back the runaways, while he himself, brandishing his sword, began exhorting those who were left, imploring them to remember their oaths, their Faith, and their Tsar. In the end, seeing little prospect of success, he exclaimed in despair "Well, then, retire; I alone am going to retake the hill."

Among the garrison were many men of the Fifth Regiment who loved their commanding officer and were touched with shame, so that voices began to be heard, "Brothers, the Commandant of the Regiment is left on the hill; we must go and rescue him." Whereupon this living wave, with Ermakov at their head, broke back up the hill. Tretyakov, taking advantage of this enthusiasm, lost no time in leading the men against the Japanese, and with him in front of the attack went Lieutenant Fetter, of the Mining Company, Ensign Ermakov, and others. In this attack the men of the various corps were so intermingled that there was no question of rearranging them in their companies.

The Japanese were already occupying the summits of Visokaya when this attack burst upon them, and so impetuously was it pushed home that not only the redoubts, but even the trenches below them, were recovered. Only a very small section of the trench on the left flank remained in the hands of the Japanese, and all attempts to drive them out of that failed. But this short length of a few paces had little importance; the hill had been recaptured, and the full credit belonged to General Tretyakov, and to his faculty of not losing his head in a moment of difficulty.

General Irman reported the occurrence in the following words: "To the Fortress Staff. From the Fifth Regiment Staff. The Japanese have been beaten from all the trenches, and the whole of Visokaya is in our hands, thanks to the energy and initiative of Colonel Tretyakov. The repairing of trenches has begun.—Colonel Irman, 12.50 a. m., November 28-29."

The Japanese were driven from the hill at about midnight. The joyful news flew through the city, which was anxiously awaiting the result of the fighting. Some idea of the general relief may be gathered from the following message received from General Stessel at 1.30 a. m.: "Hoorah. You heroes will receive worthy rewards. Thanks to Irman, to Tretyakov. I embrace you all heartily.—Stessel."

After having repulsed the Japanese, Tretyakov set to work to reorganize his command and to repair damages, which latter work included the clearing of trenches and communications, excavating collapsed blindages, and repairing the wire entanglements.

Against Flat Hill the enemy from daybreak had opened a powerful artillery fire, and after dinner they threw several mines, endeavoring thereby to destroy two machine guns which were posted in the trenches of the left flank. The machine-gun detachment, which consisted of sailors, frequently changed the position of these guns, and at last withdrew them altogether from the parapet and hid them in the trench, "to escape the attention of the Japanese gunners." With one of the guns was First-Class Seaman V. D. Perevozchikov, of the cruiser *Pallada*.

For some time the Japanese infantry had been collecting in the parallels on the slope of Visokaya, and in that nearest to Flat Hill two companies, each numbering from 250 to 300 men, were crowded. It was evident that they were preparing for an attack on Visokaya, and while awaiting the appointed hour, not anticipating any danger, some were sitting and others lying in the sap, making themselves as comfortable as circumstances permitted. Their rifles were leaning against the parapet, and in two or three places the smoke of fires was peacefully rising. On noticing this, the sailors of the machine-gun detachment quickly planted their guns in a spot from which it was possible to enfilade this parallel, and about a score of the most skilful riflemen joined them. All took careful aim, and when everything was ready they fired together.

The Japanese trench at once awoke to a scene of the most frightful confusion. The men threw themselves from side to side like madmen, in fruitless search for cover; some leaped out of this unexpected tomb and as if on wings dashed down the hill, but here the bullets caught them before they had succeeded in reaching a place of safety. In a minute or two the turmoil had ceased. The parallel was filled with dead bodies, and looked more like a combined grave than a trench, and it is needless to say that the Japanese did not again collect in it.

At 3 p. m. an attack by the Japanese infantry was made against a small portion of trench in the section of the Twelfth Company, Fifth Regiment, on the left flank of Flat Hill, near the dead ground. This section had suffered very heavily from artillery fire, and at the moment of attack was defended by only nine riflemen, the rest having been killed or wounded. The Japanese rose unexpectedly from the dead ground; the defenders opened fire on them, but some found their rifles choked with dust and had to have recourse to their bayonets. Several perished in the hand-to-hand struggle that ensued, and the rest fell back to right and left along the trench. After this the Japanese were pelted with hand grenades and fired on with rifles, and they replied in the same manner; and in this way about an hour passed.

By this success on the part of the enemy the Twelfth Company was cut in two, and volunteers were promptly called for from the two half-companies to advance simultaneously from both sides and restore connection. From the Second Half-Company there came forward Zakharov, senior sergeant of the Third Section, Sergeant Tvorogov, Corporal Yakimov, and Town Guard Vavilov, and from the First Half-Company Rifleman Polyakov, and the rest followed them. After throwing hand grenades into the trench and firing at those of the enemy who were in the act of climbing over the parapet, the volunteers of the Second Half-Company dashed forward until they had joined hands with the First Half Company.

Many dead and severely wounded Japanese lay in the trench, and among them, concealed by a traverse, were three only slightly wounded. Unaware of their presence, Tvorogov and Yakimov advanced along the trench and were promptly bayoneted. The men who rushed to their assistance took vengeance on all the Japanese who were found alive in the trench for the destruction of their brave comrades; but Tvorogov and Yakimov, who had always taken the lead in their company's charges, expired after about half-an-hour's agony.

Meanwhile, the damaged parapet was built up with Japanese corpses, and preparations were made for meeting a fresh assault, which came off almost simultaneously with that on Visokaya Hill at about 5.15 p. m. As before, the Japanese were at first successful in a few places, but were eventually driven back at all points, losing a few prisoners.

On this day, the 28th, the Russians lost about 1,000 men, and the Japanese probably about 3,000.

At 11 p. m., Staff-Captain Belozerov took over command of the hill from Captain Stempnevski I.

At that time the receipt of an order to go to Visokaya Hill amounted practically to a sentence of death. Thither daily many went, but rarely did one return. Generally, in not more than an hour after moving off, the more fortunate (wounded) were carried back on stretchers to the hospitals; the less fortunate (killed) no one troubled about, but left them on the hill.

But, after all, the conditions in November for the wounded were so horrible that it would be difficult to say who were more fortunate, they or the killed. The dead at any rate were out of pain, and for them every place was suitable, everywhere there was room. But for the wounded it was necessary to look for room; and where could they look, when all the hospitals were full, not only the beds, but even the very floors of the corridors?

In the hospitals it was customary to place the beds two together, so that each pair could take three wounded. On the news arriving that a fresh assault had begun, in order to make room for a fresh influx of wounded, all those whose wounds had begun to heal, or who could use their legs, were sent out to join the detachments of invalids, or to the ranks. For two or three days afterwards they were allowed to visit the hospital for dressing or medicine; and many used this privilege, so that towards the end of the siege as many as 3,000 daily were attending the hospitals in Arthur. But it is difficult to say how many in the ranks were really fit.

But these measures were insufficient, and during a serious attack the influx of wounded men was so great that all the available space was filled in the course of the first day.

The fighting on Visokaya followed immediately upon the assaults of the 26th November on Forts Nos. 2 and 3, so that the hospitals were full to overflowing before this fighting had even begun. During the fighting the bearers carried their wounded to the nearest hospital, and if they found a spare place they left him there. Failing this, they laid down their stretcher in the corridor without asking whether the hospital could take him in or not. But when the corridors were full and no room could be found, they had to carry him to a second hospital, and then to a third, and so on. Sometimes these journeys took many hours, if not a whole day, all the hospitals being visited in turn. In this way it not infrequently happened that the wounded man could not endure such treatment, and died before he could be crowded in anywhere. Nor was this surprising; the men were extremely exhausted with hard work, poor food, and want of rest, and their wounds, with loss of blood and physical suffering, added to their weakness. They wanted warm rooms and rest, but instead of this they were borne in the cold all round the filthy streets of Arthur, and their painful condition was exposed in all its nakedness and horror.

The stretcher bearers also were placed in a position of great difficulty. The hospitals could not receive the wounded, and there was nowhere else to take them. But what could they do? They could not leave them in the middle of the road, and yet where was there to take them?

Within the hospitals work went on unceasingly, attendants striving to clear the corridors, Sisters of Mercy attending the wounded on their arrival and trying to ease their sufferings, and surgeons with pale, tired faces performing endless operations. They worked all day and all night. Sometimes they stopped for two or three hours in the night, to begin their terrible work afresh at 6 a. m. next morning; but even then they got no rest, for they felt that those minutes of leisure were gained only at the cost of human lives.

They worked on indefatigably to the sound of shells crashing overhead and occasionally even striking the hospitals. Thus, for instance, over the Composite Hospital shells were continually shrieking; some fell in the yard and close to it, and one actually struck the room next to the operating theater. But all the same those heroic surgeons, Giubbenet and Ivanov, took no notice of the danger, and with cheery good humor went on with their work.

The Ninth Hospital was the first to receive damage, as a shell struck it in the first bombardment of the town during August, and in subsequent bombardments shells fell in the yard and outbuildings, and occasionally in the building itself. After the fall of Visokaya Hill the upper story was rendered uninhabitable. In this hospital that skilful surgeon, Krzhivets, without relief or rest day or night, performed operations unceasingly. Pale, silent, and stern of countenance, he carried out the most difficult work. For instance, under the eyes of the writer, he put fourteen stitches in the intestines of a non-commissioned officer who was wounded in the stomach, doing the operation with marvellous confidence and rapidity. The impression produced upon the writer was such that if he were ever wounded and required an operation, he would pray to be given into the hands of this man. Under his knife he would die happily.

He would also trust himself in the hands of Giubbenet and Ivanov, and also in those of the surgeon of the Red Cross Hospital, Mirotvorets, and yet.

in their case a certain amount of pity was felt for the patients, while no one pitied those of Dr. Krzhivets.

Both the Sixth Mobile and the Sixth Reserve Hospitals were seriously damaged by shells. The Dalninski Hospital, since the first bombardment, had to move four times. But every hospital was exposed to danger, and in each unnoticed but heroic men worked unceasingly without relief or rest. In fact, the surgeons in Port Arthur earned the character of heroes without fear and without reproach, gallant in heart and in their work.

The same respect is due to the Sisters of Mercy; in an unostentatious manner they also carried out most heroic work.

On the evening of the 28th of November, the gallant naval lieutenant, Deichman, fell on Visokaya Hill. It was due to his enterprise that some time previously a Japanese war vessel was blown up in Kerr Bay. This is how it happened:

The Japanese wanted to make Kerr Bay, which had been mined by the Russians, navigable to their ships, and had consequently dragged away the mines, and in this way formed a channel, which they marked by buoys, consisting of anchored barrels.

Deichman begged permission to be allowed to make a trap for the Japanese, and taking a few trusty naval volunteers on a dark night about the 13th of May, he went in one or two small boats and removed the casks to the area into which the mines had been dragged. In the greatest danger this gallant party worked the whole night without being discovered.

At dawn on the 15th of May a Japanese cruiser, probably the *Asama*, approached Kerr Bay, and guided by the casks she struck on a mine. The scene of the disaster was marked on that day by her masts, which alone rose above the surface of the water. On the 17th of May, in the presence of the Fifth Regiment at Kinchow, General Stessel publicly thanked and decorated Deichman, who also received many congratulations from the officers of the Fifth Regiment, but replied, modestly, that he had only done his duty.

After Kinchow the writer lost sight of him, but he became famous in Port Arthur for having broken through the Japanese blockade with despatches for Kuropatkin, and returned shortly before the fighting on Visokaya Hill. After this he volunteered for service on land, and having asked for an appointment in the Fifth Regiment, was given the command of the Sixth Company, which happened to be vacant.

At 6.30 on the dark evening of the 28th of November, when the storm on Visokaya Hill was at its height, and anxious watchers were awaiting news with sinking hearts, the Sixth Company stood at the headquarters, Fifth Regiment, awaiting the order to proceed to the hill; Deichman, after receiving a few final orders from General Kondratenko, came up to them and greeted them cordially as their new commander. He met with a cordial reception, and telling the men that they were ordered to the hill, and that there they would have many opportunities of becoming better acquainted with him, he marched them up and reported to Stempnevski, who was arranging an attack to drive the Japanese from the redoubt on the right. This attack was carried out from three sides by three separate parties; on the left Stempnevski himself made a demonstration with a few men using rifle fire and grenades; in the center Deichman charged in with 10 volunteers, but was immediately killed

with a bullet through the forehead; and after that 15 men, with naval Lieutenant Morozov and Ensign Ermakov at their head, advanced towards the redoubt, and after hurling a few grenades, went in with the bayonet; but most of the Japanese succeeded in getting away, except a small party who were caught sitting in a blindage. This party having been disposed of by grenades, the redoubt was finally cleared of the enemy. Both of these last-named officers distinguished themselves by many deeds of valor on Visokaya Hill.

On that same evening another gallant officer, Staff-Captain Vanikovski, commanding the Seventh Company, Fourteenth Regiment, also fell. He was killed by a stone thrown up by a bursting shell, and his men, who went out into most dangerous ground to recover his body, bitterly lamented his loss. The commander of the Fourth Company, Fifteenth Regiment, Staff-Captain Borzinski, and Staff-Captain Rozhanski, of the same regiment, were also wounded on this day by a bullet which ricocheted from Ensign Ermakov's rifle.

(To be continued.)

Alexander Macomb

ALEXANDER MACOMB (see frontispiece) was born in Detroit, Mich., April 3, 1782. He entered the United States Army as a Cornet of Cavalry, January 10, 1799, and was promoted to Second Lieutenant in February, 1801. In the reorganization of the Army in April, 1802, he was retained in the Second Infantry. On October 12, 1802, he was appointed First Lieutenant in the Corps of Engineers, and was afterward promoted as follows: Captain, January 11, 1805; Major, February 23, 1808; Lieutenant-Colonel, July 23, 1810.

At the outbreak of the War of 1812 he was the acting Adjutant-General of the Army, and fearing lest this position would prevent him from seeing active service, he transferred to the Third Artillery, in which he was appointed Colonel, July 6, 1812. As Colonel of this regiment he distinguished himself at Niagara and Fort George, and was appointed Brigadier-General, January 24, 1814, and was assigned to the command of part of the northern frontier bordering on Lake Champlain.

On September 11 of that year, in command of 1,500 regular troops and some militia, he met and defeated Sir George Prevost at Plattsburg, Vt., in command of a considerably superior British force, and forced him to retreat into Canada. For this victory he received the brevet rank of Major-General and the thanks of Congress, November 3, 1814, "for his gallantry and gallant conduct in defeating the enemy at Plattsburg on the 11th of September, repelling with 1,500 men, aided by a body of militia and volunteers

from New York and Vermont, a British veteran army greatly superior in number;" and at the same time Congress presented him with a gold medal "emblematical of his triumph."

On the reorganization of the Army in April, 1815, he was retained in the service, and in June, 1821, was appointed Colonel and Chief Engineer of the reorganized Army. He served as Chief of Engineers from this time until the 24th of May, 1828, when, after the death of Major-General Jacob Brown, he succeeded to the command of the Army with the rank of Major-General, and the title of General-in-Chief.

He commanded the Army of Florida in 1836, and died June 25, 1841, in Washington, D. C.

He was the author of "Treatise on Military Law and Courts-Martial as Practiced in the United States, 1809."



A Pioneer Company of Engineers, United States Army, complete in every detail.

SELECTED ARTICLES OF ENGINEERING INTEREST

Compiled by Henry E. Haferkorn, Librarian, Engineer School

In the lists of selected articles published the publication is referred to by the number preceding its title in the following list.

The following abbreviations will be used: I, for illustrated; D, for diagrams.

- (1) *Annales des Ponts et Chaussées*, partie technique; bi-monthly.
- (2) *American Machinist*; weekly; Thursdays.
- (3) *Canadian Engineer*; monthly.
- (4) *Canadian Society of Engineers, Bulletins*; May and December each year. *Proceedings*; monthly.
- (5) *Cassier's Magazine*; monthly.
- (6) *Cement*; bi-monthly.
- (7) *Cement Age*; monthly.
- (8) *Cornell Civil Engineer*; monthly.
- (9) *Electrical Review*; weekly; London.
- (10) *Engineer (London)*; weekly.
- (11) *Engineering (London)*; weekly.
- (12) *Engineering-Contracting*; weekly.
- (13) *Engineering Magazine*; monthly.
- (14) *Engineering News*; weekly; Thursdays.
- (15) *Engineering Record*; weekly; Saturdays.
- (16) *De Ingenieur (Hague, Holland)*; weekly.
- (17) *Journal of American Society of Mechanical Engineers*.
- (18) *Journal of Western Society of Engineers*; bi-monthly.
- (19) *Journal of Franklin Institute*; monthly.
- (20) *Journal of Royal United Service Institution (London)*; monthly.
- (21) *Proceedings, American Society of Civil Engineers*; monthly.
- (22) *Proceedings, Engineer's Club of Philadelphia*; monthly.
- (23) *Municipal Engineer*; monthly.
- (24) *Municipal Journal and Engineer*; monthly.
- (25) *Railway Age and Gazette*; weekly; Fridays.
- (26) *Revue Générale des Chemins de Fer (Paris)*; monthly.
- (27) *Scientific American*; weekly; Saturdays.
- (28) *Scientific American Supplement*; weekly; Saturdays.
- (29) *Transactions, American Society of Civil Engineers*.
- (30) *Professional Memoirs, Corps of Engineers*; quarterly.
- (31) *Journal of the Royal Artillery (Woolwich, Eng.)*; monthly.
- (32) *Royal Engineers' Journal (Chatham, Eng.)*; monthly.
- (33) *Proceedings Brooklyn Engineers' Club*; monthly.

ARTILLERY MATERIAL.

An attachment for the wheels of heavy artillery carriages. Trans. (31), Aug., 1910. I.—Design and construction of artillery wheels. (10), July 1, 1910. D.

AUTOMOBILES, MILITARY.

Automobile development in Germany. Trans. (31), July, 1910.—Military automobile as a weapon against airships. (27), July 30, 1910. I.

BRIDGES.

An unusual bridge job: Putting a center hinge in a two-hinged steel arch. (14), Aug. 18, 1910. D.—Building a concrete railroad bridge under traffic. (15), Aug. 20, 1910. D. I.—Caissons for the main piers of the new Quebec Bridge. (14), Sept. 8, 1910. D. I.—Concrete pedestal bridge abutments on the New York State Barge Canal. (14), Aug. 18, 1910. I.—Design and erection of the Missouri Bridge for the Pacific Extension, C. M. & St. P. Railway. J. H. Prior. (14), Aug. 25, 1910. D.—Eight-track bascule bridge at Campbell avenue, Chicago. C. R. Dart and S. T. Smetters. (18), Aug. 1910. I.—Erection of an eight-track rolling lift bridge. (15), Aug. 13, 1910. D. I.—Grouting masonry arches in Hamburg. (15), Sept. 3, 1910.—Hudson River Bridge at Waterford, N. Y. H. N. Peck. (14), July 14, 1910. I.—Long reinforced-concrete railway viaduct through the city of Rotterdam, Holland. (14), June 16, 1910. D. I.—Improved operation of the Brooklyn Bridge. (15), June 11, 1910.—Improving a granite viaduct. Boston & Providence Railroad. (15), Sept. 10, 1910. D. I.—The Main Street Bridge over the Buffalo Belt Line. (15), Aug. 27, 1910. D.—The Miles Glacier Bridge. (15), Aug. 6, 1910. D. I.—Mississippi River Bridge at St. Louis for the Illinois Electric Traction System. (14), July 28, 1910. D. I.—Modern highway bridge construction. F. T. Kersting. (14), Aug. 25, 1910.—New reinforced concrete bridge across the Colorado River, Austin, Tex. (14), June 23, 1910. I.—Nickel-steel eye-bars for Blackwell's Island Bridge. W. R. Webster. (29), Sept., 1909. D.—Nickel steel for bridges. J. A. L. Waddell. (29), June, 1909.—A notable bridge. (28), July 2, 1910. D. I.—Notes on the replacing of the superstructure of the Harlem River Ship Canal Bridge. H. J. Howe. (29), June, 1910. I.—A plate girder arch bridge carrying a concrete roadway. (15), Aug. 20, 1910. D. I.—The present status of reinforced concrete bridges. (15), Aug. 13, 1910.—Recent Howe truss railroad bridges. (15), Sept. 3, 1910. D.—Reconstructing a defective bridge under traffic. (14), June 30, 1910. D.—Reconstruction of the Quebec Bridge. (15), Sept. 10, 1910. D.—Replacing a short truss span by plate girders. (15), June 25, 1910. D.—The Seventh Street Bridge, Los Angeles, Cal. (15), July 2, 1910. D. I.—Some details of light highway bridge erection. (15), June 18, 1910. I.—Steel substructure, Pennsylvania Terminal Post Office. (15), Sept. 10, 1910. D.—Substructure of the American River Bridge. (15), Aug. 27, 1910. D. I.—Substructure of the Dumbarton Point Bridge. (15), July 23, Aug. 13, 1910. D. I.—Superstructure of the Mobridge Bridge on the C. M. & St. P. Railway. J. H. Prior. (15), June 11, 1910. D.—Temporary single-track lift bridge. (15), Aug. 20, 1910. D.—Tests of nickel steel riveted joints, Quebec Bridge. (15), Aug. 20, 1910. D. I.—Three-hinged arch vaulting over the Saint Martin Canal, Paris. (15), Sept. 10, 1910.—Three-hinged reinforced concrete arch bridge, Los Angeles. (15), Aug. 13, 1910. D. I.—320-foot reinforced concrete three-hinged arch of

the Grafton Bridge, Auckland, N. Z. (14), Aug. 4, 1910. I.—Typical compression members in long span bridges. E. Marburg. (15), Sept. 3, 1910. D.—The two highest masonry bridges in the world. (27), July 9, 1910. I.—Walnut Lane Bridge, Philadelphia. G. S. Webster and H. H. Quimby. (29), Dec., 1909. D. I.

BUILDING CONSTRUCTION.

The Doe Memorial Library, University of California. W. L. Huber. (15), Aug. 27, 1910. D. I.—Fire-resistant construction of building. Informal discussion. (29), Dec., 1909.

CANALS.

Depositing concrete under water on the slope walls of the Lachine Canal. H. R. Lordly. (14), Aug. 11, 1910. D.—Erie Canal. C. Prelini. (11), July 1, July 15, 1910. I.—Hoisting boats electrically. F. C. Perkins. (28), Sept. 3, 1910. D. I.—Progress on the Cape Cod Ship Canal. (15), July 30, 1910.—Replacing canal headworks, Egypt. (15), Aug. 27, 1910.—Sectional concrete lining of the Tieton Canal. (15), Sept. 10, 1910. I.—The Stockton, Cal., diverting canal. (15), June 18, 1910. D.—The Tieton Canal. E. G. Hopson. (21), Aug., 1910. D. I.

CEMENT.

Action of frost on cement and cement mortar, together with other experiments on these materials. E. R. Matthews and J. Watson. (29), Sept., 1909.—Aluminates: their properties and possibilities in cement manufacture. H. S. Spackman. (15), July 9, 1910.—Effect of Alkali water on cement mortars. A. J. Fisk. (14), Aug. 18, 1910.—German standard specifications for delivery and testing of Portland and Iron-Portland cement. (14), Aug. 25, 1910.—New German standard specifications for cement. H. Buchartz. (15), June 25, 1910. D.—Recent investigations on the constitution of Portland cement. (15), July 16, 1910. D.—Results of expansion of cement sidewalks. (15), June 25, 1910. I.

COAST DEFENSE.

Defenselessness of the Pacific Coast. Editorial. (30), Oct.-Dec., 1910.

CONCRETE, PLAIN AND REINFORCED.

Bonding of new to old concrete. E. P. Goodrich. (29), Sept., 1909.—Computation of reinforced concrete flat slabs. L. F. Brayton. (15), Aug. 27, 1910. D. I.—Concrete laying at the Gatun locks, Panama Canal. (14), July 21, 1910.—Concrete piles. H. J. Cole. (29), Dec., 1909. I.—Diagrams for designing reinforced concrete beams. F. H. Carter. (15), June 18, 1910. D.—The effect of alkali on concrete. G. C. Anderson. (29), June, 1910.—Effect of lightning on reinforced concrete sidewalks. C. Keller. (30), Oct.-Dec., 1910. I.—Effect of sodium silicate on concrete. A. Moyer. (15), July 23, 1910.—Impurities in sand for concrete. Informal discussion. (29), Dec., 1909.—Methods for the computation of reinforced concrete flat slabs. L. F. Brayton. (14), Aug. 25, 1910. D.—Notes on drilling holes in concrete. J. R. Taft. (15), Sept. 3, 1910.—Office methods in a concrete designing office. (15), June 11, 1910. D.—Progress report of a special committee on concrete and reinforced concrete. (29), March, 1910.—Reinforced concrete barge on the Panama Canal. (14), July 28, 1910.—Reinforced concrete yacht pier, Glen Cove, N.Y. (15), Aug. 20, 1910. D.—Sodium silicate and concrete. A. Moyer. (28), July 23, 1910.—Standard specifications for concrete reinforcement bars adopted

by the Association of American Steel Manufacturers. (14), June 16, 1910.—A steel and reinforced concrete grandstand. (15), Sept. 3, 1910. D. I.—320-foot Reinforced concrete three-hinged arch of the Grafton Bridge, Auckland, N. Z. (14), Aug. 4, 1910. I.—Two concrete locomotive coaling stations. W. E. Witte. (15), Sept. 3, 1910. D.

CONTRACTS AND SPECIFICATIONS.

Agreements for building contracts. W. B. Bamford. (29), June, 1910.—Damages for delay on Isthmian Canal contracts. W. B. King. (15), Aug. 27, 1910.—Government specifications in the United States. F. Percival. (13), Sept., 1910.—Necessity for standardizing contract forms. R. W. Creuzbaur. (15), July 2, 1910.—Standardizing public works contracts. R. W. Creuzbaur. (14), July 28, 1910.

CONVEYORS.

Belt conveyors for handling crushed stone. (15), Aug. 6, 1910. I.—Mechanical cargo handling. (15), Aug. 20, 1910. I.—Traveling and slewing tower transporter. (10), July 1, 1910.

CORPS OF ENGINEERS, U. S. ARMY.

Brig. Gen. W. H. Bixby, Chief of Engineers, U.S.A. Biographical note, with portrait. (15), June 11, 1910.—Alexander Macomb. Biographical note, with portrait. (30), Oct.-Dec., 1910.

CRANES, HOISTS, ETC.

The Erasmus Electric Hoist. (28), July 30, 1910. I.

COST KEEPING.

A system of cost keeping. M. S. Falk. (29), Sept., 1909.

DAMS.

British views regarding earth dams. (15), July 9, 1910.—The Chandiere Dam, Ottawa, Canada. D. L. McLean. (14), June 30, 1910. D. I.—Construction of the Cataract Dam, Sydney, N. S. W. L. A. B. Wade. (14), June 23, 1910. I.—Cracks in the Concrete core-wall of the Little Bear Valley Dam, Cal. (14), Aug. 25, 1910. D.—Curved dams in New South Wales. (15), Aug. 27, 1910.—Eagle Dam and Reservoir, Rio Grande project, U. S. Reclamation Service. (14), Aug. 18, 1910. I.—Experiments on small weirs and measuring modules. J. C. Stevens. (14), Aug. 18, 1910. D. I.—New Bear Valley Dam, Cal. (14), June 23, 1910. D.—Reinforced concrete deck dam, Pulaski, Va. (15), Aug. 6, 1910. I.—Rolling dams for irrigation in Mexico. (15), Sept. 10, 1910. D. I.—The Shoshone Dam of the U. S. Reclamation Service. D. W. Cole. (15), July 23, 1910. D. I.—St. Andrews Rapid Dam. H. P. Borden. (10), Aug. 12, 1910. D.—Stoney-gate Dam in the Albula Canyon for the Hydro-electric Power Plant of the city of Zurich, Switzerland. K. E. Hilgard. (14), Aug. 25, 1910. I.—Stresses in masonry dams. W. Cain. (29), Sept., 1909. D.

DREDGES AND DREDGING.

Combination bucket and suction dredger. (10), Aug. 26, 1910. I.—The Fruhling suction dredge. J. Reid. (22), July, 1910. I.—Light draft stern-wheel suction dredge for navigation improvement on the Niger. (14), June 16, 1910. I.

ENGINEERING PRACTICE.

Precarious expedients in engineering practice. J. Hawkesworth. (29), June 1910.

EXCAVATION.

New excavating, hoisting, and conveying machine. (15), Aug. 27, 1910. I.

EXPLOSIONS.

Powder magazine explosion at Hull, Quebec. (14), June 23, 1910. D.—A remarkable explosion. (10), Aug. 12, 1910.

FLOODS.

Floods of the Mississippi Delta: their causes and suggestions as to their control. W. D. Pickett. (29), June, 1909.—Proposed structure to prevent future damage from floods at Paris. (14), July 28, 1910. D. I.—Report of the flood on the Zuni River, Sept. 6, 1909. H. F. Robertson. (14), Aug. 25, 1910. D.—Report of the Paris Flood Prevention Commission. (15), Aug. 6, 1910.

FORTIFICATION, FIELD.

Redoubts and field fortification. W. D. Connor. (30), Oct.-Dec., 1910. I.

FOUNDATIONS.

Foundations for the new Singer Building, New York City. T. K. Thomson. (26), June, 1909. D. I.—Hand-driven steel sheet piling, Bush Terminal, Brooklyn. F. T. Llwelllyn. (15), Aug. 20, 1910. I.—Pneumatic caisson foundations, Whitehall Building, New York. (15), June 18, 1910. D. I.—Underspinning and foundation work for a loft building. (15), Sept. 3, 1910.

FUEL.

Coke oven gas as fuel for boilers. (15), Sept. 10, 1910.

HARBORS.

The harbor of Constantza. A. Gradenwitz. (28), Aug. 20, 1910. I.—Harbors of Great Britain, with some reference to those of North Europe and North America. J. V. Nimmo. (14), Aug. 11, 1910.

HYDRO-ELECTRIC PLANTS.

The Boulder hydro-electric plant. (15), July 30, 1910. D. I.—General review of hydro-electric engineering practice. F. Koester. (13), July, Aug., Sept., 1910. I.—Glenwood Hydro-electric Plant, Central Colorado Power Co. (15), June 25, 1910. D. I.—Hydro-electric development and high tension practice. P. H. Thomas. (30), Oct.-Dec., 1910. I.—Hydro-electric development of the Arizona Power Co. R. S. Masson. (15), Aug. 20, 1910. I.—Hydro-electric development of the Great Western Power Co. (15), June 11, June 18, 1910. D. I.—Hydro-electric development of the Michoacan Power Co. I. C. McBride. (15), Aug. 27, 1910. D. I.—Hydro-electric power in Canada. C. B. Smith. (29), Dec., 1909. D.

INLAND NAVIGATION.

Outline for a report on a waterway improvement. G. A. Zinn. (30), Oct.-Dec., 1910.—Steel barges for inland waterways. (15), June 11, 1910. D.—Traffic through the Soo Canals and the Detroit River. (15), July 30, 1910.

IRRIGATION (see Public Works).

LIGHT-HOUSES

The Baltimore Light-house. W. E. Craighill. (30), Oct.-Dec., 1910. I.

LIGHTNING.

Effect of lightning on reinforced concrete sidewalks. C. Keller. (30), Oct.-Dec., 1910. I.

LOCKS AND LOCK GATES.

Canadian hydraulic lift lock. W. J. Francis. (10), June 10, 1910. I.—

Rebuilding the Galena lock gates. S. Edwards. (30), Oct.-Dec., 1910. I.—Siphon lock on the barge canal at Oswego. (15), July 30, 1910. D. I.

MATERIALS.

Annual meeting of the Society for Testing Materials. (14), July 7, 1910.—Corrosion of iron and steel. A. S. Cushman. (15), July 9, 1910.—Corrosion of iron embedded in concrete. G. F. Shaffer. (15), July 30, 1910. I.—New apparatus for measuring deformations in materials. H. C. Berry. (15), June 11, 1910.—Novel test for resistance to corrosion. (14), June 16, 1910. D. I.—Progress report of special committee on steel columns and struts. Discussion. (29), March, 1910. D.—Some exposure tests of structural steel coatings. C. M. Chapman. (14), Aug. 18, 1910. I.—Steel sheeting and sheet-piling. L. R. Gifford. (29), Sept., 1909. D.—Strength of steel in I-beams. E. L. Hancock. (15), July 9, 1910. D. I.—Tests of built-up steel and wrought-iron compression pieces. A. N. Talbot and H. F. Moore. (29), Dec., 1909. I.

MILITARY ENGINEERING.

General report on the Engineer Troops of the Italian Army. Don R. Marin del Campo. (32), Aug., 1910.—Redoubts and field fortification. W. D. Connor. (30), Oct.-Dec., 1910. I.—The "Scientific Corps" in Spain. J. C. Dalton. (31), July, 1910.—A pioneer company of Engineers. (30), Oct.-Dec., 1910. I.

MOTOR SLEDGES.

Motor sledges for the Antarctic expedition. (11), Aug. 26, 1910. I.

ORDNANCE.

New type of siege ordnance. (10), June 10, 1910. D.—Vickers' ordnance at the Japanese-British Expedition. (11), Aug. 12, 1910.

PANAMA CANAL.

Concrete laying at the Gatun Locks, Panama Canal. (14), July 21, 1910.—Machinery and equipment on the Panama Canal works. (10), Aug. 12, Aug. 26, 1910. I.—Present condition at Panama. (10), May 27, June 3, 1910. I.—Reinforced concrete barges on the Panama Canal. (14), July 28, 1910.—Water supply for the lock canal at Panama. (29), June, 1910.

PAVEMENTS.

Review of Chicago paving practice. P. E. Green. (29), March, 1910. I.

PERIODICAL LITERATURE.

Selected articles of engineering interest. H. E. Haferkorn. (30), Oct.-Dec., 1910.

PRESERVATION OF TIMBER.

Notes on wood preservation and creosote production in Europe. (22), July, 1910. I.—Wood preservation from an engineering standpoint. C. T. Barnum. (18), June, 1910.

PREVENTION OF DUST.

Waste sulphite liquors for dust prevention. (15), Aug. 27, 1910.

PUBLIC WORKS

District engineer work in the Philippines. W. Goldsmith. (14), July 7, 1910. I.—Future river and harbor policy of President Taft. (14), July 28, 1910.—New irrigation Board of Engineer Officers of the Army in connection with certain U. S. Reclamation Service projects. (14), Aug. 4, 1910. I.—Proposed method for raising the *Maine* from Havana Harbor. (14), Aug. 4, 1910. D. I.—Raising the *Maine*. (27), Aug. 20, 1910. I.—Prospects for engineering

work under the Government. (14), June 16, 1910.—River and harbor appropriation divided between new improvement and maintenance. (14), Aug. 25, 1910.

RECLAMATION OF LAND (see Public Works).

RESERVOIRS.

Outlet control of Little Bear Valley Reservoir. F. E. Trask. (29), March, 1910. I.

RETAINING WALLS.

Comparative section of thirty retaining walls and some notes on retaining wall design. F. H. Carter. (14), July 28, 1910. D.

RIVER AND HARBOR WORK (see Public Works).

RIVER ENGINEERING.

Conditions on the Lower Colorado River. (15), July 2, 1910.—Foreshore protection. (10), July 15, 1910. I.—Improvement of the Ohio River. W. L. Siebert. (29), June, 1909. D.—Outline for report on a waterway improvement. G. A. Zinn. (30), Oct.-Dec., 1910.—Protection of banks on the Missouri River. G. A. Lofland. (15), Aug. 27, 1910. D.—River bank protection. (15), Aug. 6, 1910.—River protection work on the Kansas City Southern Railway, near Braden, Okla. J. A. Lahmer. (29), March, 1910. D.—A 30-year record of flow for the Columbia River. (14), June 30, 1910.

RIVER GAGING.

Deepest current-meter work and the depth of mean velocity: Mississippi River Commission gaging. (14), July 14, 1910.—What stream gaging indicates as to the run-off from forested and barren areas. (14), June 30, 1910.

RIVER SURVEYS.

Methods and cost of midwinter surveying. The St. Louis and Cloquet River surveys, Minn. C. R. Adams. (14), July 28, 1910. I.

ROADS.

Construction of sand clay roads in western Kansas. W. S. Gerhart. (14), June 30, 1910.—Has experience demonstrated that the oiling of roads is the most satisfactory or economical method of preventing dust and preserving the road surface? Informal discussion. (29), Dec., 1909.—Petrolithic and other systems of road and street improvement at El Paso, Tex. (14), Aug. 4, 1910.—Progress report of special committee on bituminous materials for road construction. (29), March, 1910.—Sampittic surfacing. W. W. Crosby. (29), Sept., 1909.—Road roller of improved design with novel form of front truck. (14), July 7, 1910. D. I.

RUSSO-JAPANESE WAR.

Final assault on 203-Meter Hill. Transcript. (30), Oct.-Dec., 1910. I.

SEA WATER, ACTION OF. (See, also, Cement, Concrete, Subaqueous concrete.)

Behavior of hydraulic compounds in sea water. H. Buchartz. (15), Aug. 27, 1910. I.—Effect of included sulphuric acid on the strength and behavior of Portland cement exposed to sea water. (14), July 7, 1910.—Wave-break added to a concrete sea wall. (14), Aug. 18, 1910. D.

SEARCHLIGHTS. (See, also, Automobiles, Military.)

Electric light and its use in war. Trans. (31), July, 1910.—Field automobile searchlights. R. W. (32), July, 1910. I.—Notes on searchlights. R. W. (32), July, 1910. I.

SUBAQUEOUS CONCRETE.

Depositing concrete under water on the slope walls of the Lachine Canal. H. R. Lordly. (14), Aug. 11, 1910. D.—Failure of concrete piles under ocean pier at Long Beach, Cal. L. A. Waterbury. (14), July 21, 1910. I.—Laying concrete under water. (14), Aug. 4, 1910.—Long-time tests on concrete in sea water. A. Poulsen. (14), July 7, 1910.

VIBRATION OF BOATS.

Vibration of boats. Editorial. (30), Oct.-Dec., 1910.

WATER POWER.

Conservation of water powers. L. B. Stillwell. (14), July 7; (15), July 2, 1910.—Utilization, preservation, and conservation of water power. L. G. Carpenter. (15), July 23, 1910.—Water-power sites. W. H. Taft. (15), Sept. 10, 1910.

WATER SUPPLY: TOWNS.

Hypochlorite disinfection of the water supply of Toronto, Ont. T. A. Murray. (14), July 21, 1910. I.—Operating results, Cincinnati Water Purification Plant. (15), Sept. 25, 1910.—Purification of the water supply of Steelton, Pa. J. H. Fuertes. (29), March, 1910. D.—Results of double filtration experiments at Albany. (15), Sept. 3, 1910.—Use of hypochlorite in connection with pre-filtration. (15), June 25, 1910.—Water pollution and water purification at Jersey City, N. J. C. E. A. Winslow. (18), Aug., 1910.—Water purification plant of the Chicago Stock Yards. (14), Sept. 8, 1910.—Water Purification Plant, Putnam, Conn. (15), Aug. 13, 1910. D.—Water-supply system of Santiago, Cuba. H. F. Cameron. (15), July 30, 1910. D. I.

WATER WORKS.

Some rules for water-works appraisals. (15), Sept. 10, 1910.—Valuation of the Fond du Lac water works. (15), Sept. 3, 1910.

WHARVES.

Municipal wharf at Montgomery, Ala.: A novel solution of the river loading problem. G. C. Scherer. (14), July 14, 1910.—Reinforced concrete wharf of the United Fruit Company at Boras del Toro, Panama. T. H. Barnes. (29), March, 1910. D. I.—Wharf construction at Fort Mason, Cal. (15), Aug. 6, 1910. I.

Editorial Notes

The Defenselessness of the Pacific Coast

On May 19, 1910, the Hon. James McLachlan, of California, made a speech in the House of Representatives on the "Defenselessness of the Pacific Coast," which is of vital interest, not only to the Army, but also to every citizen of this country who has the welfare of the country at heart and who desires a continuance of the wonderful prosperity and peace that have marked the development of this country for the last half century.

Mr. McLachlan introduced the following resolution for the consideration of the House:

Resolved, That the Secretary of War be, and he is hereby, directed, if not incompatible with the public interest to submit to this House, with the least practicable delay, a report showing in detail:

First. The condition of the military forces and defenses of the Nation, including the organized militia.

Second. The state of readiness of this country, with particular reference to its preparedness to repel invasion if attempted (a) on the Atlantic or Gulf coasts; or (b) on the Pacific Coast.

Third. The additional forces, armaments, and equipments necessary, if any, to afford reasonable guaranty against successful invasion of the United States territory in time of war.

His speech was an explanation of the reasons which led to the introduction of the foregoing resolution. It was not incendiary, except as some people have a habit of calling the truth incendiary and anarchistic. To a person who is willing to look the facts squarely in the face and abide by the consequences of logical reasoning, the speech is a plea for peace measures and not for those of war. He advisedly introduced the speech at this time when all nations are at peace and there is no rumor of war nor cause for acute disagreement with any other nation.

He recognizes what has been admitted for many years, That a

struggle for the mastery of the Pacific is almost inevitable, and that if such a struggle is to be purely one of mercantile competition and not one of armed strife, the United States must be in position to defend itself against any competitor that it must meet in those waters. That this country is bound to be one of the foremost bidders for the supremacy of the Pacific there is no question of doubt. That other countries recognize this and are unwilling to acquiesce without a struggle, if there is any chance of success, will hardly be disputed; and the only way to make the struggle a peaceable one of mercantile competition is for this country to be prepared at all times for the undesirable and unhappy contingency of an armed struggle.

The people of the Pacific Coast are intensely and vitally interested in this matter, because a successful armed struggle for the mastery of the Pacific by a foreign nation involves the occupation of the Pacific Coast of the United States by that nation. That this can not be prevented by the Navy alone while stationed in the Atlantic Ocean is unquestioned by anyone who has made a study of the matter, and while we may not agree absolutely with the deductions of Mr. Homer Lea in regard to the rapidity and ease with which that occupation can be accomplished, there is no question but what there is a great deal of truth in the "Valor of Ignorance," by Mr. Lea, referred to by Mr. McLachlan.

Mr. McLachlan apparently admits that it is inadvisable to remove the entire fleet from the Atlantic Ocean at the present time, or to divide the fleet between the two oceans before the Panama Canal is completed, and therefore practically admits that the protection of the Pacific Coast must lie in the Army and not in the Navy.

Many people seem to be imbued with the idea that since the sea-coast defenses of the Pacific Coast are nearly completed, the country is safe against invasion from that quarter. Mr. McLachlan points out the fallacy of this and indicates the true object of sea-coast defenses, which is to protect a port from naval attack only and has but little bearing upon the subject of defense against invasion by a hostile landing force.

In continuing that subject, he points out the insufficient number

of Coast Artillery troops to properly man the existing fortifications, and then leads up to the subject of the mobile army. In a very few words, he makes an inventory of our military preparedness in men and material and points out the deficiency in numbers of the regular Army in this country and of the general unpreparedness of the National Guard to be first line troops.

As stated before, the speech will not be considered incendiary except by those who are unwilling to face the truth, or by those whose interests do not lie on the Pacific Coast and who are so absorbed in their own personal desires and occupations that they are unwilling to view the matter from the National instead of from an individual point of view. Mr. McLachlan puts it squarely before Congress as to whether this subject is a local one or a National one, and his questions must be considered pertinent if the latter view be taken.

Inasmuch as any report from the Army will be viewed with suspicion by the great mass of the people, even if it is read at all, it is to be sincerely hoped that the subject will be investigated by a committee of Congress whose decision can not be suspected of being influenced by any other consideration than the broad question of National welfare.

Flexibility in Boats

An interesting article appears in the "Motor Boat" of April 10, 1910, concerning the flexibility in boats, by Mr. C. G. Davis. The author refers to the fact that, in the old days, unless a boat was limber and gave to the waves, it was considered no good. Modern motor boats have been forced to sacrifice this flexibility in order to keep the propeller shaft properly aligned. Even with the stiffest construction compatible with the allowable weight, it is practically impossible to prevent the boat from buckling to a certain extent under the action of the waves and, in a motor boat, unless some provision is made in the shafting to compensate for the flexibility of the boat, a great deal of power is lost in the bearing that should be utilized in making speed.

The author indicates the new style of shafting that allows the motor boat to be flexible and still not waste power in the shaft bearings. To purchasers of motor boats, for inspection or other purposes, this is of considerable interest, because one of the best known facts about motor boats is the difficulty of obtaining their guaranteed speed under service conditions. Prospective purchasers of motor boats will be interested in this article, and owners may find an easy means of adding a few miles per hour to the speed of boats which they already possess.

Pioneer Troops

(See illustration on page 544)

In the new Field Service Regulations, 1910, engineer troops are officially divided into pioneer and pontonier companies and battalions. Each battalion consists of three companies. One pioneer battalion is to be assigned to each division, including cavalry divisions, and one pontonier battalion is to be assigned to each field army.

The illustration accompanying this article shows a pioneer company for service with an infantry division complete in every detail as to men, animals, and vehicles. The company was made up from A and D Companies, First Battalion of Engineers, at the Camp of Instruction held at Gettysburg, Pa., during July, 1910, and is under command of Capt. C. W. Otwell, Corps of Engineers.

The following list shows the organization of such a company:

- 1 captain.
- 2 first lieutenants.
- 1 second lieutenant.
- 1 first sergeant.
- 1 quartermaster sergeant.
- 12 sergeants (1 as mess and 1 as stable sergeant).
- 18 corporals.
- 2 cooks.
- 2 musicians.

64 privates (first class), and 64 privates (second class): 1 as cook, 1 as horseshoer, 1 as farrier, 1 as saddler, 3 as drivers, 2 as wagoners.

3 wagons, 4-mule (tool, explosives, etc.):

6 pack mules.

2 riding mules.

2 field wagons.

Total enlisted, 164.

The following are mounted:

1 captain.

2 first lieutenants.

1 second lieutenant.

2 sergeants.

3 corporals.

1 cook.

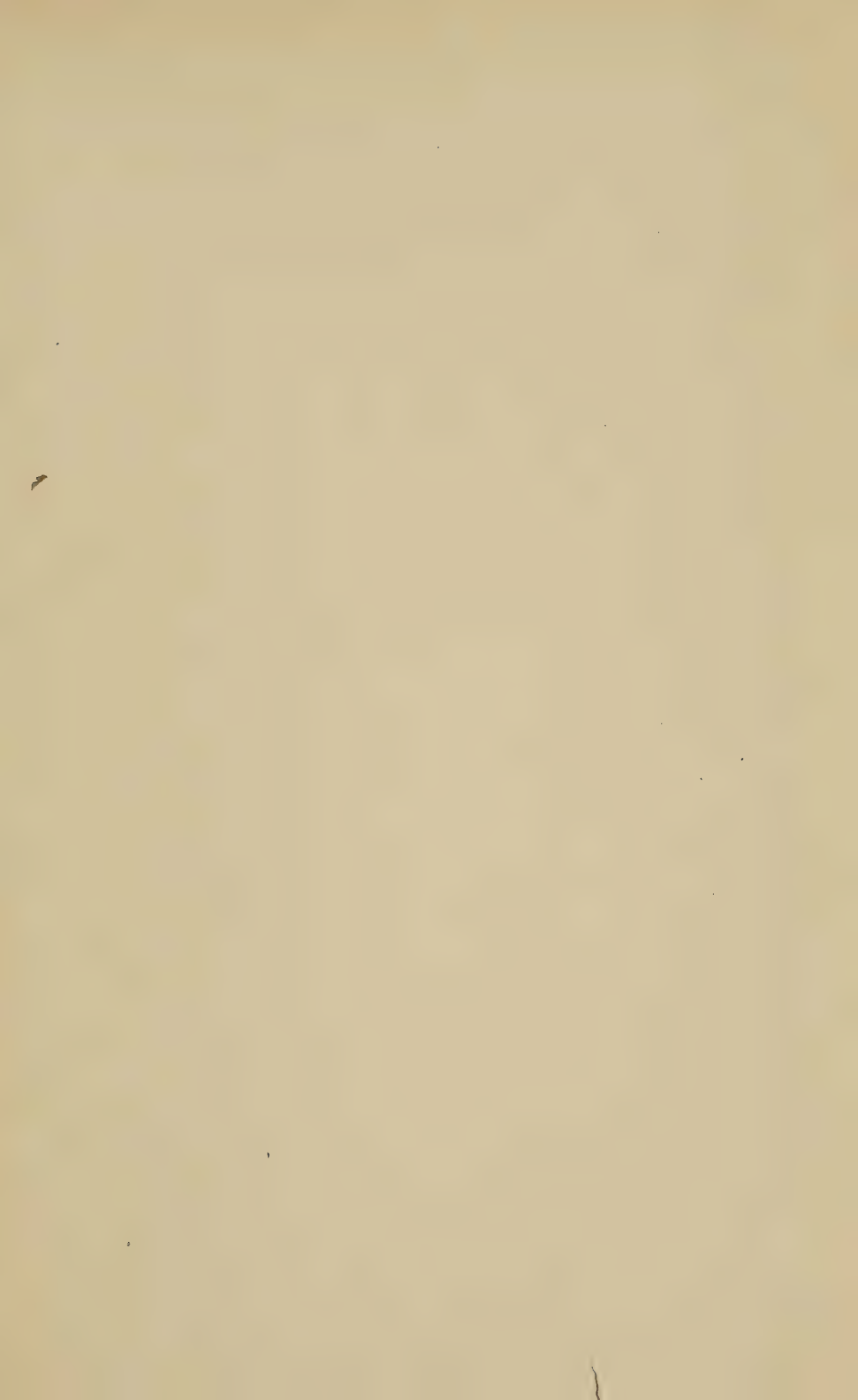
18 privates, first and second class.

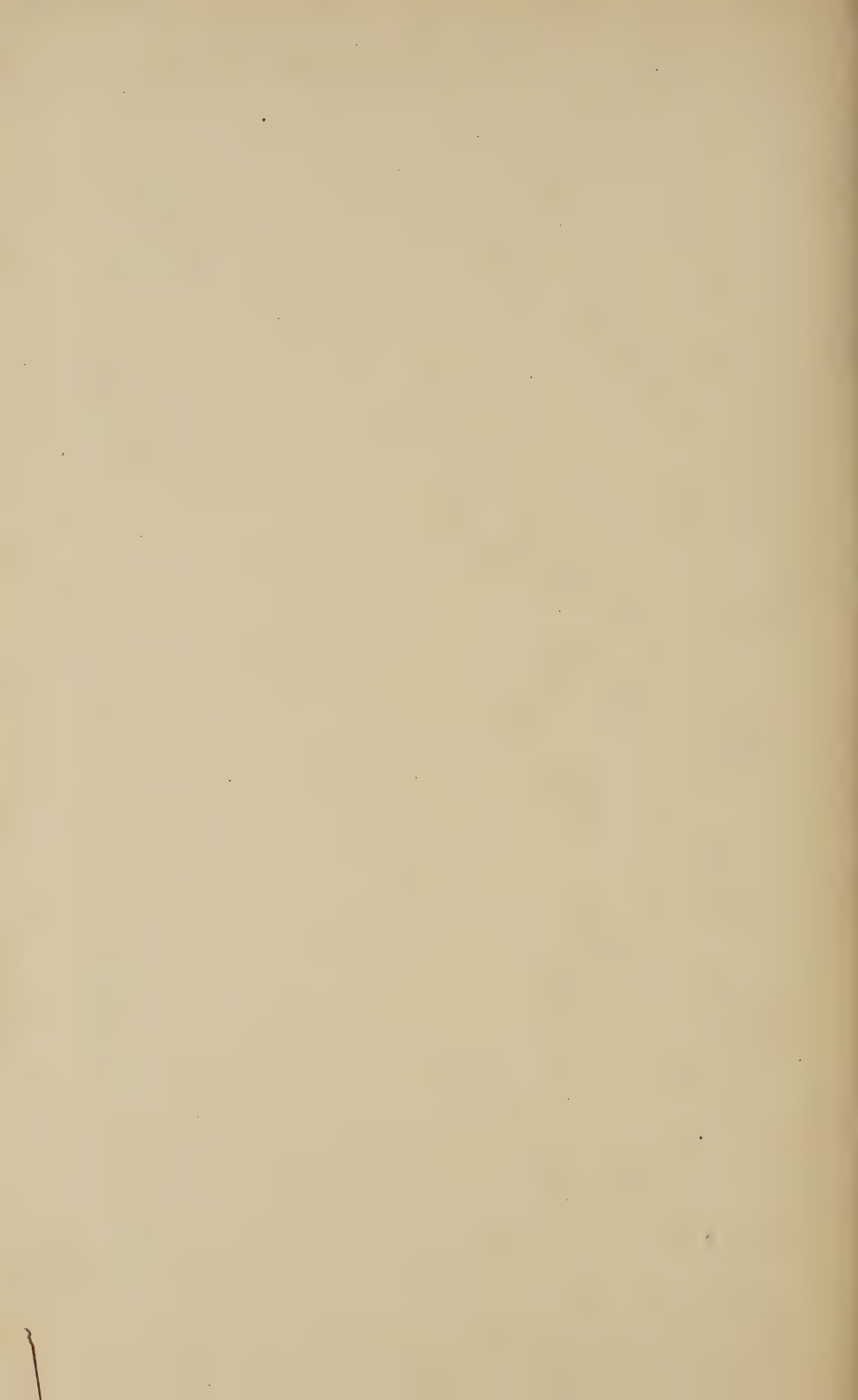
For duty with cavalry divisions, the strength of a foot pioneer company, as given above, is decreased by 4 sergeants, 8 corporals, 26 first and 26 second class privates, giving a maximum enlisted strength of 100. In such companies all officers and enlisted men (except the drivers, wagoners, and 1 cook) are mounted.

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